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Volume I

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This is the final environmental impact statement (EIS) prepared by EPA for the Metro Denver Sludge Management Plan. The Metropolitan Denver Sewage Disposal District #1 plan calls for development of a pipeline and drying/storage complex some 27 miles to the east of the Commerce City plant. Up to 107 dry tons per day of anerobically digested sludge would be pumped to the drying basins. After drying and storage of approximately a year, the dried sludge product would be sold or distributed for a variety of uses. It is contemplated that municipal parks, irrigated farms, sod farms and home gardens would constitute the principal use areas.

The report describes the project, alternatives, environmental impacts, and mitigating measures. The most severe potential impact is expected to be on the groundwater in the vicinity of the site. Other impacts include added water consumption, odor problems, effects in the site area, effects in areas of use. Recommendations are made for basin lining, control of uses, heavy metals limits, etc.

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EPA Project Number: C0080341

by

U.S. ENVIRONMENTAL PROTECTION AGENCY
REGION VIII, DENVER

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Approved By: Alan Merson
Regional Administrator

Alan Merson

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Metropolitan Denver Sewage Disposal District No. 1
Denver, Colorado
EPA Project No. C-0080341

( ) Draft (x) Final Environmental Impact Statement

1. Name of Action: (x) Administrative ( ) Legislative

2. Description of Action: The Metropolitan Denver Sewage Disposal District No. 1 (Metro) has proposed to construct the necessary facilities to transport sludge to a site in Adams County for air drying in earthen basins, stockpiling in above-ground windrows and distributing to the farming community to be reused on land for growing crops. It is envisioned that anaerobically digested sludge--digester construction already being funded by EPA--in the amount of 107 dry tons per day will be produced in the design year 1985. The types of lands expected to receive sludge from Metro include city parks in the metropolitan area, sod farms, mine spoil sites, irrigated farms, nonirrigated farms and home gardens. It is assumed that application rates will be consistent with the nutrient uptake rate of the growing plants and that sludge application on a given piece of land will be terminated when the heavy metal loading limit specified for that particular land will have been reached.

3. Environmental Impacts:

A. At the sludge drying and distribution center:

(1) At least 243 ha [600 acres] of dryland wheat production will be lost. Production on the remaining 775 ha [1320 acres] will depend upon Metro research and demonstration activities.

(2) Groundwater quality could gradually be deteriorated by the leachates from the bottom of the drying basins, carrying salts, including nitrates, to the water table. EPA will require lining of the basins to minimize leachate movement to the water table.

(3) An increased amount of water up to 6,000 cubic metres [1.5 million gallons] per day, more than that now consumed in the existing sludge disposal practices of Metro will be carried in sludge, purge water and additional irrigation water to the Adams County site, slightly reducing flows in the South Platte River downstream of the Central Plant.

(4) A sizable saving in transport energy (8 million KWH/yr) will be realized over the current method of sludge disposal. In addition, about 20 million KWH/yr of equivalent energy will be saved if all the sludge is successfully marketed to replace commercial fertilizer. If the digester gases are coverted into usable energy, another major saving of 50 million KWH/yr will be realized.

(5) Odors generated in the drying basins-- may occasionally be objectionable to the surrounding farmers and other residents. Grant conditions will limit the use of the site for digester upset disposal to underground injection at agronomic rates.

(6) Severe effects on soils, plants and the groundwater would occur if the site were to be used for a disposal area. However, EPA grant conditions will prohibit use of the site for disposal except as provided under (5), above.

B. At the sludge reuse areas:

(1) Introduction of excessive heavy metal elements, particularly cadmium, into the soils and the food chain, and their gradual concentration magnification in various tissues, could pose a health hazard to humans and possible reduction in yield of crops. These hazards are the greatest in home gardens and on irrigated farms. EPA will recommend limits for use and indicate areas where sludge should not be applied.

(2) Longevity of certain parasites such as Ascaris beyond the drying/storage period may comprise a public health hazard, especially in nome gardens and city parks.

(3) Water quality degradation from salt and nitrate movement below the root zone in home gardens, irrigated farms, city parks and sod farms is a long-term, though minor, cumulative impact.

(4) Air quality may be degraded by particulates and aerosols during severe windstorms, especially in dry-farmed areas. This impact will be limited because of the generally cohesive nature of dried sludge.

(5) Soil productivity will improve (although salinity will gradually increase) with the addition of the organic matter in the sludges, resulting in improved vegetative growth and crop production.

(6) Conservation of natural resources, especially fossil fuels and plant nutrients, is a prime reason for, and the most salient beneficial impact of, the project.

C. At the Lowry Bombing Range sludge disposal area, if the current disposal method is continued:

(1) Heavy metal elements may be introduced into the food chain through grazing of livestock on the sludge-amended fields.

(2) A potential public health hazard to the operators at the Bombing Range is posed by the high pH raw sludges now deposited.

(3) There is a threat to groundwater quality from the movement of salts (particularly nitrates) below the root zone. Surface water is also affected during periods of runoff.

(4) Even though soil structure and water-holding capacity will increase, excessive salt and nutrient loading rates will somewhat limit the increase in productivity.

(5) The sludge drying practices and transport method to carry sludge to the Bombing Range use large amounts of energy.

(6) Large amounts of chemicals are used to reduce odors and dewater the sludge under present operation.

(7) The Metro Central Plant will experience increases in loadings of suspended solids, BOD and ammonia due to return of supernatant from the anaerobic digesters.

4. Alternatives: Sixteen alternatives, ranging from no action to heat treatment-air drying-landfill to vacuum filtration-pipeline transport and recycling with solid wastes were considered. They are summarized in Tables 1 and 2.

5. Distribution: The distribution list is presented in Appendix H.

6. Draft Statement Sent to Council on Environmental Quality: 29 July 1976.

7. Final Statement Sent to Council on Environmental Quality:

Piles of Ordure

Do you know what these piles of ordure are,
Collected at the corners of streets,
Those carts of mud carried off at night from streets,
The frightful barrels of the nightman,
And the fetid streams of subterranean mud
Which the pavement conceals from you?

All this is a flowering field,
it is green grass, it is mint, thyme and sage;
It is game, it is cattle,
it is the satisfied lowing of heavy kine;
At night it is perfumed hay,
it is gilded wheat,
it is bread on your table,
it is warm blood in your veins,
it is health, it is joy, it is life!

Victor Hugo, in Les Miserables (1862)

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SECTION I

This section provides an introduction to the problem of sludge handling at Metro and a brief description of the proposed land-recycling system. It also explains the role of EPA in the project and its requirements for fulfilling the National Environmental Policy Act.

SECTION I

BACKGROUND

INTRODUCTION

Victor Hugo's Paris was discarding some five million francs worth of sewage per year, by his estimates, in the mid-19th Century. His graphic and prophetic lament on the wastage of this valuable material was in part motivated by the untenable social and economic conditions dramatized in *Les Miserables*. While many underlying conditions have drastically changed and new types of social problems and technologies have since emerged, it appears that we have come full circle back to the realization of the potential resource value of our waste products.

The outbreaks of cholera in Europe in the early 19th Century led to the beginnings of sanitation systems. Today, in many developing countries which have not adopted such systems, the rate of incidence of enteric diseases is still vivid testimony to the need for the protection of human health. The potential health problems of waste application to land have multiplied since Victor Hugo wrote his masterpiece by the introduction into the sewers of large quantities of exotic elements and by the sheer increase in the size of our metropolitan areas. Thus, realistically, waste products of human beings are both a valuable resource and a potential environmental hazard.

Placement of sludge upon the land is at once the oldest and the most recent concept in the use and/or disposal of this material. It is an old practice in all parts of the world. Before communities evolved into complex social structures that required proper sanitation facilities, land disposal of human wastes was the most logical approach. In many developing countries, these wastes are even now directly utilized for crop fertilization, and as such they are traded as a valuable commodity.

Application of sludge to land is a relatively new concept in the more technologically advanced countries--particularly in the United States--because of recent concerns over water quality degradation caused by the various other existing sludge disposal practices. Modern widespread consciousness of the energy and resource values that could be derived from sludges is another impetus for land application. Thus, in a recent revision to EPA's grant regulations and procedures, it is stipulated that:

> *Grantees must participate in the National Energy Conservation Program by fostering, promoting, and achieving energy conservation in their grant programs. Grantees must utilize to the maximum practical extent the most energy-efficient equipment, materials, and construction and operating procedures available.*
> *(Reference 1)*

A main factor causing the great difference between the "new" land application and reuse of sludges and the "old" fertilizer use of human wastes is the altered chemical properties of the respective materials involved. Modern plumbing systems, and industrial inputs into municipal sewers have changed the character of sludges by introduction of potentially toxic and otherwise dangerous materials. This, coupled with the ever present microorganisms, including pathogens, makes sludge application to land a very sensitive matter which must be subject to careful design, surveillance and management control.

The environmental impact of land application of sludge includes the beneficial impacts (such as conservation of energy and nutrients and improvement of physical characteristics of the soil) and adverse impacts (such as potential degradation of ground and surface water quality and soil chemical characteristics as well as human health and the food chain). The degree and extent of these impacts vary qualitatively and quantitatively from one proposed application site to another, sometimes in an entirely opposite fashion. Therefore, the impacts of sludge application are clearly identified with the category of land use to which the sludge might be applied. For each category, typical sites were selected and studied in detail, and the conclusions are expected to be typical for other areas of *similar* character and use.

THE REASON FOR THIS DOCUMENT

The National Environmental Policy Act (NEPA) requires every Federal agency to prepare a detailed statement on environmental impact for each of its major proposed actions significantly affecting the environment. In this case, the Environmental Protection Agency is proposing to approve a facilities plan for the management and disposal of sludge, by the Metropolitan Denver Sewage Disposal District No. 1.

EPA's responsibility for the approval of a wastewater treatment facility is given to it under Public Law 92-500, known as the

Water Pollution Control Act Amendments of 1972.

EPA has decided that approval of this plan constitutes a major, significant action under NEPA and is therefore preparing a detailed environmental impact statement. An environmental impact statement (EIS) must consider the environmental impacts of a proposed action, both short and long term (and especially the irreversible, adverse kinds), and alternatives to the action.

Under Title II of the Water Pollution Control Act Amendments, EPA is given authority to distribute construction grant fundings for municipal wastewater treatment facilities. This section of the Act defines a three-step process of planning (Step I), design (Step II) and construction (Step III) that must be fulfilled for an eligible grant applicant to construct a facility with Federal funds.

The Step I process works as follows: an applicant who is certified through a State priority system prepares a facilities plan. EPA will pay 75 percent of the costs of such a plan. Before a plan can proceed to the design and construction phase, the plan must be approved by EPA. Design (Step II) review is delegated to the State. EPA has determined that the approval process of a facilities plan constitutes the Federal action under NEPA.

Sludge treatment and disposal units are considered an integral part of the wastewater treatment process and hence are eligible for funding. Section 212(A) of the Act defines such facilities to include land acquisition costs if they are part of the treatment process:

> *The term "treatment works" means any devices and systems used in the storage, treatment, recycling, and reclamation of municipal sewage or industrial wastes of a liquid nature ... including site acquisition of the land that will be an integral part of the treatment process or is used for the ultimate disposal of residues resulting from such treatment.*

The Congressional philosophy for the need to recycle and reclaim many of the pollutants in sewage, including sludge, in a beneficial manner is clear in Sections 201(d), (e) and (f) of the Act:

> *(d) The Administrator shall encourage water treatment management which results in the construction of revenue producing facilities providing for--*
>
> *(1) the recycling of potential sewage pollutants through the production of agriculture, silviculture, or aquaculture products, or any combination thereof;*

> . . .
>
> *(4) the ultimate disposal of sludge in a manner that will not result in environmental hazards.*
>
> *(e) The Administrator shall encourage waste treatment management which results in integrating facilities for sewage treatment and recycling with facilities to treat, dispose of, or utilize other industrial and municipal wastes, including but not limited to solid waste and waste heat and thermal discharges. Such integrated facilities shall be designed and operated to produce revenues in excess of capital and operation and maintenance costs and such revenues shall be used by the designated regional management agency to aid in financing other environmental improvement programs.*
>
> *(f) The Administrator shall encourage waste treatment management which combines "open space" and recreational considerations with such management.*

In addition to the environmental considerations required under NEPA, EPA must determine whether the facility considered in this plan meets the goals of the Federal Water Pollution Control Act Amendments of 1972 stated above.

The Metropolitan Denver Sewage Disposal District No. 1 (referred to as "Metro") has submitted a facility plan to EPA and the State of Colorado to process and dispose of its sludge by recycling it to the land. This EIS considers the effect such a plan would have with regard to requirements of the following Federal environmental laws, among others:

(1) Federal Water Pollution Control Act Amendments of 1972
(2) Clean Air Act (of 1970)
(3) various legislation regarding noise, solid waste and pesticides
(4) Historic Sites, Buildings and Antiquities Act of 1935
(5) the Endangered Species Act of 1973 and Endangered Species Conservation Act of 1969 and amendments

Because sludge is being considered for use on products that could reach the human and animal food chains, the expertise of the Food and Drug Administration and the Department of Agriculture will be solicited. All appropriate State standards and regulations will have to be met, including the Solid Waste Disposal Sites and Facilities Act requirements. This act is administered jointly by the State Health Department and the Board of County Commissioners for the county in which the proposed site is to be located.

While the Department of Health makes recommendations, the County must approve specific site locations for any solid waste disposal area. State law defines sludge as a solid waste for purposes of this act.

Agency expertise and public opinion were sought by EPA for this project. The draft EIS has been distributed for review, and EPA has conducted public hearings to solicit additional information. This document is the final EIS for the Denver Metro Sludge Management Plan. This document contains a resolution of any issues raised in the course of the review of the draft EIS. EPA has determined that all of the important issues have been satisfactorily resolved, and after at least 30 days from the release of the final EIS, this facility plan will be approved.

EPA assigned the consultant Engineering-Science, Inc. to assist the agency in reviewing this very complex plan, to obtain additional expertise and to help prepare the EIS document. This document represents the position of the Environmental Protection Agency regarding this plan except where the consultant's own recommendations or positions are explicitly identified.

HISTORY OF THE PROJECT

The Metropolitan Denver Sewage Disposal District wastewater treatment facilities were originally constructed in 1966 with a design capacity of 5.15 cu m/sec [117 mgd]. The overall BOD reduction goal was 80 percent. Sludge processing involved dewatering through dissolved air flotation, vacuum filtration, flash drying and/or incineration. At that time, it was expected that the relative proportions of raw primary sludge, anaerobically digested sludge and undigested waste-activated sludge would be such that the vacuum filter would produce a filter cake solids concentration of 22 to 25 percent.

By 1967, the District realized that the proportion of waste-activated sludge in the mixture was much larger than had been expected, giving rise to increased difficulty in dewatering the sludge mixture (achieving only 14 to 18 percent solids concentration of the filter cake). Thus, the need for chemicals for vacuum filtration more than doubled, and the increased moisture content overloaded the design capacity of the flash dryer-incinerator. Corrosion of the stainless steel components of the dryer-incinerator resulted from the heavy doses of ferric chloride used in sludge conditioning, further compounding the problems with the sludge handling system.

This problem became intolerable in the fall of 1968. More than half of the evaporative capacity of the dryer-incinerator had become unavailable because of mechanical problems; and activated sludge was accumulating in the biological treatment system, rapidly deteriorating the effluent quality. Therefore, lagoons were constructed for the winter months of 1968 and 1969. Odors generated in these lagoons brought about loud complaints and forced the District to shift to land disposal of the filter cake in May 1969. Since that time, land disposal, with various types of equipment, at various rates and under different conditions, has been practiced at an abandoned portion of the Lowry Bombing Range, some 40 km [25 miles] southeast of the treatment plant.

Some of the land application operations were conducted by District personnel, while others were performed by contractors. Odor problems resulting from the method of disposal used by contractors gave rise to adverse neighborhood reactions and complaints to Arapahoe County Commissioners. A public hearing was held on 20 June 1972 at which the District was committed to a new, revised land application method aimed at eliminating odor and fire hazards (Reference 3). The new method has since been utilized during dry-weather conditions, as described in Section IV under Land Application at Lowry Bombing Range. Inclement weather operation is similar to standard sanitary landfilling of solid wastes.

In 1971, the District consultants prepared an expansion plan for the central plant and recommended an agricultural reuse scheme for the sludges produced (Reference 4). After two public meetings with residents of the proposed reuse area in the winter of 1972-1973, some revisions were made, and a new agricultural reuse program was prepared by the District (Reference 5). The system has since been further refined in concept, and in February 1975 a four-volume sludge management plan was published, comparing alternatives, describing the recommended agricultural reuse scheme in detail and assessing the environmental impact of the recommended plan (Reference 6).

That report comprises a facilities plan, which was submitted to the U.S. Environmental Protection Agency on 27 February 1975. Earlier, applications for a Step I grant for the sludge management plan had been made to the State and to EPA (on 19 November and 22 November 1974, respectively). On 9 June 1975, the Regional Administrator of the U.S. Environmental Protection Agency sent a "Notice of Intent to Prepare an Environmental Impact Statement" for the proposed sludge management program of the Metropolitan Denver Sewage Disposal District No. 1.

On 30 June 1975, EPA authorized Engineering-Science, Inc. to prepare an Environmental Impact Statement on the proposed action in the plan in accordance with all relevant legislation and policies and the regulations of EPA. EPA required an additional evaluation of the environmental impact to off-site areas being considered by Metro for land application of sludge. Engineering-Science presented a preliminary draft EIS to EPA incorporating the analysis of off-site impacts. The draft EIS was written by Engineering-Science under EPA management using much of the information in the preliminary report prepared by Engineering-Science.

Since release of the draft EIS on 29 July 1976, EPA has solicited comments and conducted several public hearings in order to receive input on all issues. The results of these comments clearly indicated that several issues needed a more thorough analysis and resolution. This final EIS is, therefore, being presented in two volumes. Volume I is the updated version of the draft EIS released last year. Volume II contains a more thorough discussion of those issues which were determined to be of primary importance. Volume II also contains copies of the letters and written comments which were received relating to the project. EPA reponses to points raised in the letters are listed next to each letter.

THE PROPOSED ACTION

The sludge management plan proposed by Metro involves treatment, pipeline transport, drying, distribution and application on land of anaerobically digested sludge from the Metropolitan Denver Sewage Disposal District No. 1 sewage treatment plant in Commerce City. Figure 1 shows the location of various components of this plan in the Denver Metropolitan area.

All of Metro's sludge would first receive anaerobic digestion treatment at the central plant before further disposal. This process stabilizes the sludge and reduces odor and pathogens. EPA recently gave the District a $5.5 million grant to construct anaerobic digesters at the central plant.

The sludge would then be transported by pipeline to a drying/storage center site located in western Adams County near Irondale Road and about 18 kilometers [11 miles] southeast of Barr Lake. There the sludge would be dried in open basins and stored for future use. This processing site would also be used for marketing, research and demonstration areas, and as a disposal site on occasion.

Metro contemplates marketing the dried or liquid sludge to local dryland and irrigation farmers, for municipal parks, for mine-land reclamation, and perhaps for individual garden use. At worst, Metro could dispose of the dried sludge in a sanitary landfill if no markets were available.

Land areas that might utilize the sludge extend from the AMAX mine spoils site, near Berthoud Pass, to many of the park areas in the metropolitan Denver areas.

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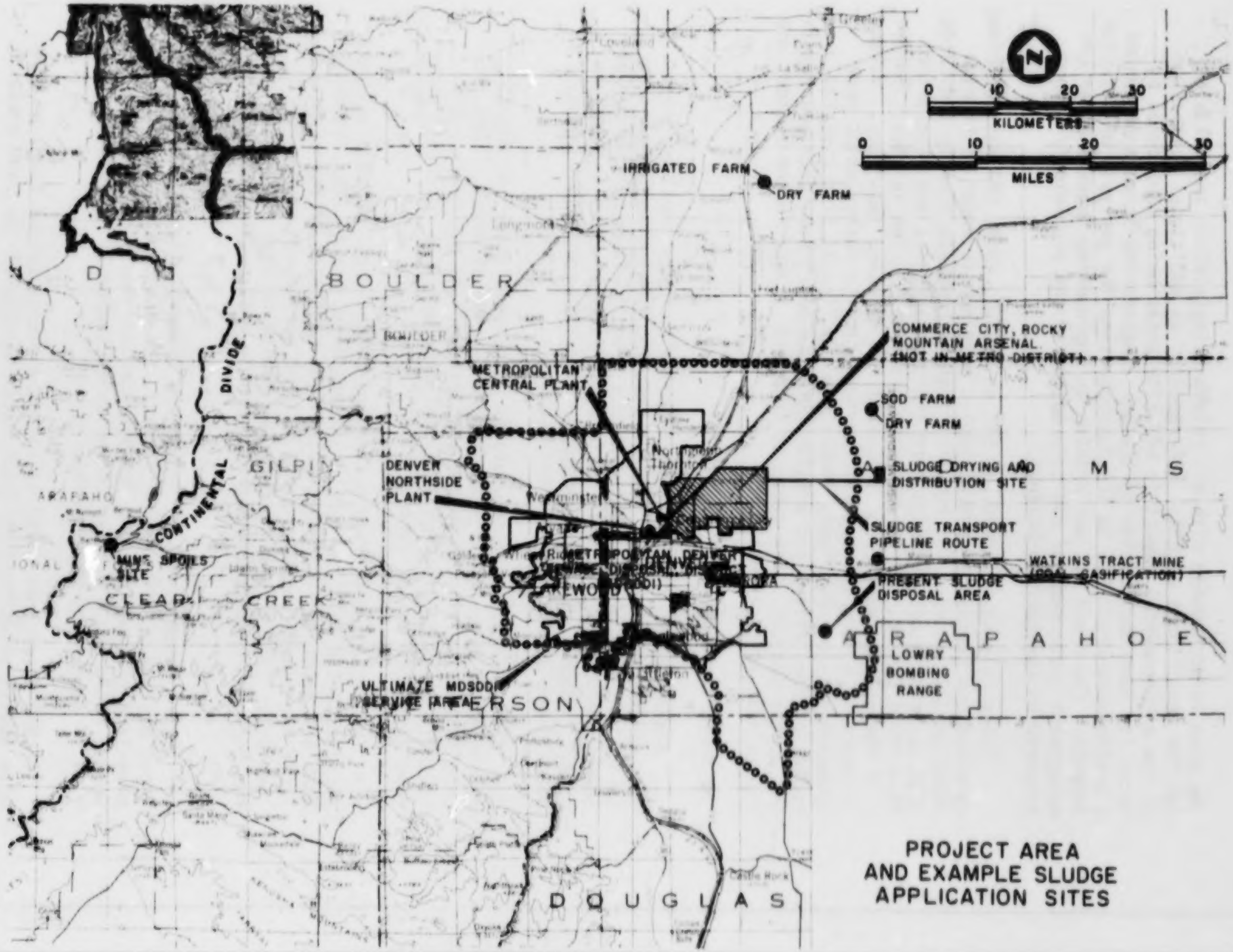
FIGURE 1


IRRIGATED FARM
DRY FARM
0 10 20 30 KILOMETERS
0 10 20 30 MILES
N
BOULDER
D
DIVIDE
CONTINENTAL
GILPIN
CLEAR CREEK
MINE SPOILS SITE
METROPOLITAN CENTRAL PLANT
DENVER NORTHSIDE PLANT
COMMERCE CITY, ROCKY MOUNTAIN ARSENAL (NOT IN METRO DISTRICT)
SOD FARM
DRY FARM
SLUDGE DRYING AND DISTRIBUTION SITE
A D A M S
SLUDGE TRANSPORT PIPELINE ROUTE
WATKINS TRACT MINE (COAL GASIFICATION)
METROPOLITAN DENVER SEWAGE DISPOSAL DISTRICT (MDSDD1)
PRESENT SLUDGE DISPOSAL AREA
A R A P A H O E
LOWRY BOMBING RANGE
ULTIMATE MDSDD1 SERVICE AREA
JEFFERSON
D O U G L A S

PROJECT AREA
AND EXAMPLE SLUDGE
APPLICATION SITES

It is proposed that air-dried sludge be trucked to application sites of the types described above and incorporated into the top layers of soil for ready use of nutrients by plants and improvement in the physical condition of soils. A very important assumption implicit in the environmental analysis of the proposed action is that sludge application rates (metric tons per hectare per year) and quantities (ultimate metric tons per hectare) recommended for a given piece of land, and other required cultural practices, will be adhered to by the recipients of the materials. The Colorado Department of Health has developed regulations for the treatment, storage, dispersion, and use of stabilized liquid and dried sludge (reference 130). Administration and enforcement of these regulations is the responsibility of the Colorado Department of Health.

The proposed project will encompass primarily Adams County, Colorado but will also include the City and County of Denver and perhaps portions of Arapahoe, Weld, Douglas, Elbert, Jefferson and Clear Creek counties. In fact, the cost of transport of air-dried sludge may become the main factor limiting the distance the material is shipped for land application.* For the purposes of environmental impact analysis, six representative land application sites are selected, as shown on Figure 1.

The service area contributing wastewaters to the sewage treatment plants, which in turn produce sludges from the wastewaters, is most of the metropolitan Denver area, comprised of more than 20 political entities. Excluded from the service area at present are the separate districts of Commerce City, Rocky Mountain Arsenal, Glendale, Littleton and Englewood.

In order to construct facilities considered in any one of the alternatives (excluding the no-action alternative) discussed in Section II for the full projected sludge generation rate of 150 dry metric tons [166 tons] per day, a capital expenditure ranging from $2.2 to $29 million would be required, depending on the alternative ultimately selected. The currently recommended alternative, described in detail in Section IV, has a capital cost of $17.8 million as evaluated by Engineering-Science without including cost of the digesters which have already been constructed at a cost of $6.5 million.

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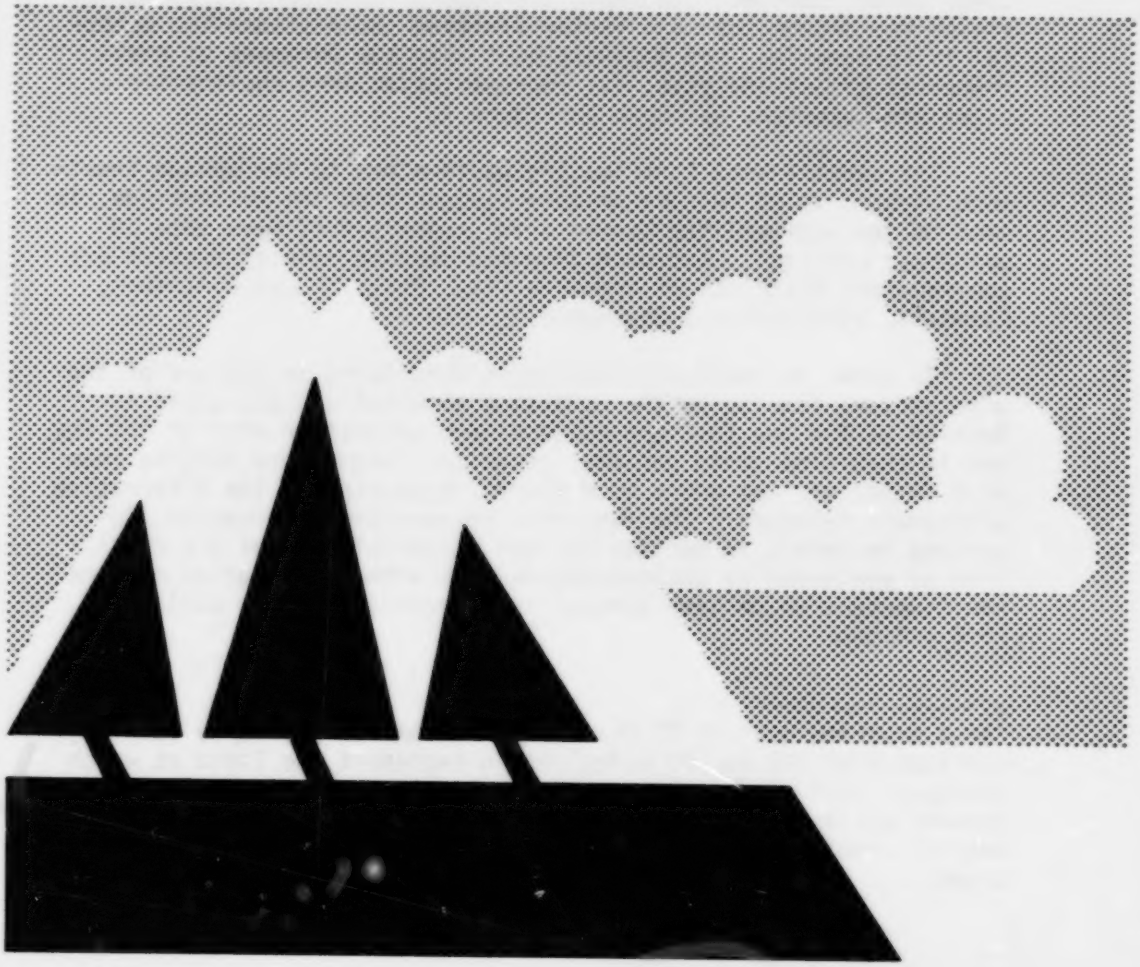
*At a trucking cost of $0.08/cu meter-kilometer [$0.10/cu yd-mile], a distance of 100 km [60 miles] would represent the limit at which transport cost of dried sludge (with 5 percent nitrogen and 50 percent solids content) equals the current price of equivalent commercial chemical fertilizer nitrogen ($0.55/kilogram [$0.25/lb]) alone.

Financing the Project

If approved, the U.S. Environmental Protection Agency would pay 75 percent of the grant-eligible portion of the capital cost if further Congressional funding became available, and the District would bear the remaining 25 percent, as provided by the Federal Water Pollution Control Act as amended in 1972.

The local share (25 percent) of the capital cost would have to be borne proportionately by the users; i.e., the individuals, industries and businesses using the District's sewerage facilities. Approval of this plan would allow EPA to reimburse Metro for 75 percent of the eligible design costs of this project.



SECTION II

10-a

This Section considers the alternatives to the proposed project. It looks at the historical development of alternatives and provides a comparative evaluation of reasonable alternatives, using environmental, engineering and cost parameters. Areas where alternatives were considered include processing and disposal, site locations and transportation.

SECTION II

ALTERNATIVES TO THE PROPOSED ACTION

INTRODUCTION

The National Environmental Policy Act requires Federal agencies to consider "alternatives to the proposed action" in every environmental impact statement. The law does not specify how thorough the alternatives must be, but courts have interpreted it to mean that a "reasonable" number of alternatives must be considered, especially any which may have merit in reducing the negative environmental impacts of the project as originally proposed.

This very broad definition of alternatives suggests that not only are very broad "total system" alternatives to be considered but, where particular features of a given proposal may have unusually severe impact, subalternatives within a system should also be evaluated. In the case of Metro Denver's proposal, site location alternatives or drying basin design alternatives might be subalternatives worthy of consideration.

A second factor must be borne in mind in the review of alternatives for a construction grants program project. EPA does not initiate a proposal for construction grant funding; that is the prerogative of any legal wastewater management district. Upon certification by the State, a district evaluates alternatives and develops a plan. The plan is then sent to EPA for final review. Although EPA has developed guidelines to assist grant applicants in order to make them aware of EPA's responsibilities in considering project alternatives, it is inevitable that the applicant will view the alternatives from a somewhat different perspective than will EPA.

To overcome this difficulty, EPA will give equal consideration to all alternatives but will recognize the effort that has been invested in the development of the proposed project. Only if there are significant environmental or other objections to the proposed overall system will a wholly different system be advanced. Even within a given proposal, however, major changes could be required if the situation so warranted.

This Section describes the historical background of Metro District planning leading to the development of alternatives and to the present proposal; compares total system alternatives; and reviews subalternatives to both the proposal and the existing system.

HISTORICAL DEVELOPMENT OF ALTERNATIVES

The Metro Denver Central Plant, built in 1965, is a secondary biological treatment facility. The plant not only processes residual solids from its own aqueous-phase treatment units but also handles anaerobic digested sludge pumped from the Denver Northside Plant. Sludge treatment and disposal has always been problematical at the plant, as evidenced by the fact that Metro has received a number of research grants to evaluate alternative sludge treatment processes.

When the Metro plant was built, flash-dry incinerators were installed to dry sludge for reuse as a soil conditioner in local parks. Because of operational problems, Metro abandoned the incinerators in 1971 in favor of dewatering on vacuum filters and disposal by surface landspreading at the Lowry Bombing Range. Subsequently, complaints about odors forced Metro to modify its method of sludge disposal from surface landspreading to landspreading and incorporation into the soil at Lowry.

In 1971, Metro hired the firm of CH2M-Hill to develop plans for the Central Plant expansion, including an evaluation of alternatives to the present sludge treatment and disposal system, which was becoming increasingly expensive. CH2M-Hill studied and evaluated from an engineering point-of-view three basically different sludge treatment and disposal systems:

1. The present Metro system.
2. Multiple hearth incineration.
3. Land disposal of digested sludge.

While the incineration and land disposal alternatives were felt to be close in overall costs and much preferable operationally to the present system, Metro adopted the recommendation of a beneficial reuse system because of an environmental "net benefit". In its land recycling proposal, Metro would have sprayed anaerobically digested sludge on about 2,400 ha [6,000 acres] of farmland either owned and operated outright by Metro or leased to farmers.

When Metro presented this option to the farming community in western Adams County, it encountered considerable resistance. Farmers objected to the loading rates, the effect of having Metro entering the farming business in a large-scale operation and potential effects of odors on land values and health in the area where the sludge would be stored. As a result, Metro concluded that more land would probably be needed to accommodate lower loading rates and became less enthusiastic about engaging in a farming operation itself.

CH2M-Hill was authorized to evaluate in more detail the land recycling alternatives and in March 1973 produced a study entitled "An Agricultural Reuse Program" (Reference 5). This study evaluated in much more detail a comprehensive approach to land recycling, using the latest information then available. The report considered issues such as various sludge characteristics and their effects on the land; water-rights issues; state-of-the-art composting and landspreading systems; fertilizer considerations; loading rates for semi-arid areas; and the types of crops most likely to benefit from sludge applications. A number of land application alternatives were evaluated in the study. The more promising systems identified were drying beds with application to agriculatural land, permanent subsurface injection on Metro-owned land and recycling on private farm land with short-term injection on Metro-owned land. Two other alternatives (spray irrigation or subsurface injection on privately owned dry farmland, and irrigation of cropland owned by Metro) were eliminated because of high cost and water-rights problems.

The report included a preliminary site evaluation which served as a basis for a more detailed site evaluation in the facilities plan (considered below). A preliminary design configuration for the most favored alternative, recycling on private land with short-term injection on Metro-owned land, was presented in the report.

Metro remained committed to the concept of land recycling but required the facilities planner to develop a more comprehensive review of all alternatives. In the facilities plan, a wide range of processing and disposal alternatives was evaluated and eight overall processing and disposal alternatives were evaluated in detail. These included:

1. The existing system--"no action",
2. anaerobic digestion--pipeline transport to a drying/distribution facility--beneficial reuse,
3. dewatering by filter presses--incineration--landfill,
4. heat treatment--dewatering on vacuum filters--landfill,
5. heat treatment--pipeline transport--drying--landfill,
6. heat treatment--vacuum filtration--incineration--landfill,
7. anaerobic digestion--dewatering by filter presses--composting--beneficial reuse, and

8. dewatering by filter presses--composting--beneficial reuse.

The facilities planners recommended the second alternative: i.e., anaerobic digestion, pipeline transport to a drying/distribution facility and beneficial reuse. This alternative became Metro's proposed system and is the principal focus of this particular EIS process.

In June 1975, EPA retained Engineering-Science (ES) to review the facilities plan and develop the EIS. Part of Engineering-Science's task was to evaluate the existing alternatives and to propose additional alternatives that appeared promising. A total of 17 alternatives for the processing and disposing of sludge were developed and evaluated for this EIS, including the eight alternatives studied by CH2M-Hill.

Table 1 shows the 17 alternative systems evaluated by Engineering-Science. The basic form of disposal is shown next to the process description. Cost information includes present-worth values with and without anaerobic digestion as a sunk cost, with and without an eight percent inflation rate and with and without revenue. Generally, cost information showed that many of the process options were close in overall costs, but land recycling became much more cost-effective when revenues, inflation and sunk costs were considered. Alternatives in which Metro sludge would be processed together with municipal refuse also appeared to be economically advantageous.

Further evaluation might be warranted if these latter types of systems were to be developed. However, the Colorado legislature failed to act on a Denver Regional Council of Governments (DRCOG) bill sponsored to develop a solid waste recycling system. Therefore, while the systems are promising, the possibility that an actual system might be developed in the near future seems unlikely. Metro has indicated that incineration is their preferred alternative if the land recycling proposal is not implemented

Environmental, engineering and cost factors considered, Engineering-Science also concluded that the "apparent best alternative" involved the Metro land recycling proposal. The Engineering-Science evaluation is contained in Appendix A, which summarizes the pertinent assumptions made in evaluating the alternative systems.

COMPARATIVE EVALUATION OF SLUDGE TREATMENT SYSTEM ALTERNATIVES

In considering the work performed by the consultants and the Metro District, a useful perspective can be gained by comparing the disposal element in each alternative, since this is the element of a sludge management system that has the most significant environmental impact. The processing alternatives generally have a relatively small environmental impact; the most important in-plant consideration is the selection of a combination of processes that will efficiently and economically produce a treated sludge with the requisite characteristics for each particular disposal mode. Thus, the comparative evaluation of sludge management alternatives for the Metro system has as its focus the disposal elements of the alternatives.

EPA recently finalized sludge management guidelines (Reference 79) that provide an indication of the way in which the agency approaches the issue of sludge disposal from an environmental point of view. The guidelines recognize that disposal of the solid material in sludge can have significant impact on the environment; disposal can simultaneously affect air, land and water and may encompass such varied considerations as human health, animal health, plant growth and the protection of ground and surface water from pollution. A basic distinction made by the guidelines in considering the final disposal of sludge is the division of management techniques into those in which sludge is utilized as a resource and those in which sludge is not used for any beneficial purpose. Examples of beneficial use include land recycling or incineration for heat or power, while in the case of nonbeneficial disposal, landfilling or incineration would simply dispose of the unwanted sludge without any return benefit.

Semantic confusion surrounds the word "disposal." In a generally accepted sense, the word is taken to mean the last step in the sludge handling process, regardless of whether beneficial reuse is involved. In the distinction often made, the word "disposal" is used only to indicate those forms of sludge management where no beneficial reuse occurs.

The basic intent of disposal is simply to take the sludge, as an unwanted residual material, out of the sewage treatment process and put it into some other system where it is relatively "harmless." An environmental concern that must be kept in mind, however, is that a residual material like sludge is never destroyed by a disposal process but simply converted to another form of matter and/or energy that continues to exist in the biosphere.

A distinction between "beneficial" and "nonbeneficial" disposal methods worth noting is that a beneficial method allows some re-entry of previously unwanted materials into the socioeconomic system; the nonbeneficial system simply puts the residual material into larger environmental systems--air, land or water. As a way of maintaining this distinction, disposal systems are referred to in this EIS as beneficial or nonbeneficial.

Table 1. SUMMARY OF SLUDGE SYSTEM ALTERNATIVES EVALUATION[a]

(millions of dollars)

Alter-native number	Description of alternative	Basic disposal method	Cost comparisons							
			Anaerobic digestion costs included				Anaerobic digestion not included (sunk cost)			
			Unadjusted for inflation		8% inflation		Unadjusted for inflation		8% inflation	
			A[b]	B[c]	A	B	A	B	A	B
1A	Existing system--waste-activated and other sludges trucked to Lowry Bombing Range for landspreading	predominantly land disposal (spreading) with some landfilling	24.1	24.1	34.3	34.3	24.1	24.1	34.3	34.3
1B	Existing system with anaerobic digestion	land disposal (spreading)	24.7	24.7	30.1	30.1	18.6	18.6	26.4	26.4
2	Anaerobic digestion, pipeline transport, air drying and beneficial reuse (product: 100 percent air-dried sludge)	land recycle	24.0	19.3	17.7	10.8	17.8	13.1	14.0	7.1
3	Filter presses, incineration, landfill of ash	incineration	24.2	24.2	26.8	26.8	24.2	24.2	26.8	26.8
4	Heat treatment, vacuum filtration, landfill	land disposal	22.5	22.5	25.9	25.9	22.5	22.4	26.0	26.0
5	Heat treatment, air drying, landfill	land disposal	33.3	33.3	30.2	30.2	33.3	33.3	30.2	30.2
6	Heat treatment, vacuum filtration, incineration, landfill of ash	incineration	23.6	23.7	23.6	23.6	23.7	23.7	23.6	23.6
7	Anaerobic digestion, filter presses, compost (product: 100 percent nutrient-enriched composted sludge)	land recycle	30.3	19.6	35.1	19.3	24.2	13.5	31.4	15.6
8	Filter presses, compost (product: 100 percent nutrient-enriched composted sludge)	land recycle	34.0	17.0	45.1	20.1	33.9	17.0	45.1	20.1
9	Anaerobic digestion, centrifugation, compost (product: 100 percent nutrient-enriched composted sludge)	land recycle	33.8	25.9	40.1	28.5	27.6	19.8	36.3	24.8
10	Anaerobic digestion, pipeline transport, air drying, compost (product: 50 percent air-dried sludge; 50 percent nutrient-enriched composted sludge)	land recycle	28.8	20.5	24.4	12.3	22.7	14.4	20.7	8.6

11	Anaerobic digestion, centrifugation, landfill	land disposal	26.4	26.4	30.8	30.8	20.2	20.1	27.1	27.1
12	Anaerobic digestion, pipeline transport, air drying, landfill, compost (product: 33 percent air-dried sludge; 33 percent nutrient-enriched composted sludge; remainder to landfill)	land recycle and land disposal	26.9	20.7	24.5	12.4	22.8	14.5	20.9	8.7
13	Anaerobic digestion, vacuum filtration, compost (product: 100 percent nutrient-enriched composted sludge)	land recycle	28.4	20.5	33.8	22.2	22.2	14.4	30.1	18.5
14	Vacuum filtration, compost (product: 100 percent nutrient-enriched composted sludge)	land recycle	27.0	14.5	36.4	18.0	30.0	14.5	36.4	18.0
15[d]	Anaerobic digestion, vacuum filtration, pipeline transport to solid waste recycling plant	conversion	16.8	16.8	17.8	17.8	10.6	10.6	14.1	14.1
16[d]	Vacuum filtration, pipeline transport to solid waste recycling plant	conversion	10.1	10.1	13.3	13.3	10.1	10.1	13.3	13.3

[a] By Engineering-Science, Inc.

[b] Without revenue.

[c] With revenue.

[d] Sludges containing less than 25 percent solid materials would require the expenditure of additional resources for the removal of water.

The Congressional philosophy expressed in the Water Pollution Control Amendments of 1972 makes it apparent that the Congress was very much concerned with developing and promoting beneficial ways to use both sludge and treated wastewater. In the portions of the Act quoted in the first Section of this EIS, beneficial disposal of sludge can be accomplished either separately by the wastewater treatment entity or in combination with municipal solid waste systems. Because cost, engineering, institutional and, to a certain extent, environmental considerations differ between these two approaches, they are distinguished in the comparative evaluation that follows. A separate wastewater district might find it very uneconomical to incinerate sludge for power purposes, but, in combination with municipal refuse incineration, the system could prove attractive.

Table 2 compares environmental impact, engineering considerations, institutional factors and costs as they relate to a number of courses of action. The alternative courses of action are organized in three groups--nonbeneficial disposal, separate beneficial use and combined municipal refuse and sludge beneficial use. It should be noted that the ranking shown in the Table is, at present, simply serving as a guide in the process of comparison; it is not yet being used as a decisive factor in the selection of alternatives.

The comparative evaluation shows the general preferability of separate land recycling schemes. Were the DRCOG solid waste recycling alternatives a real possibility, some of these alternatives would be more attractive. Metro has evaluated air basin drying versus composting approaches and decided upon the former as the method of land recycling. There appear to be no outstanding reasons from EPA's point of view as to why one should be chosen over another in this case. Recent work on composting sludge shows great environmental and economic promise (Reference 129).

Other disposal and recycling systems do not fare as well for a variety of reasons. Incineration (whether heat or power benefits are gained or not) involves air quality problems and is highly energy-demanding with Metro sludge. Land disposal methods such as landfill or land spreading do not rate as high overall because of greater adverse environmental impact, little or no positive benefit and higher costs. Other schemes involve unproven technology or are associated with higher costs.

It is concluded, from a review of all the available information at hand, that some form of land recycling, utilizing air-dried anaerobically digested sludge, is a generally environmentally sound and cost-effective alternative for the Metro District. At this point in time, EPA does not feel that a further evaluation of altogether novel sludge handling and disposal systems need be considered; a more detailed discussion is found in Volume II, Issue IV-2.

However, in view of the fact that Metro had an ongoing sludge handling and disposal system at the Lowry Bombing Range that would be replaced by a different system, EPA felt that the alternative of continued use of the Lowry disposal system (perhaps modified to a certain extent) must be considered in detail. The National Environmental Policy Act requires a Federal agency to review the null or "no-project" alternative. It seems reasonable for EPA to question whether a new system, even with the inclusion of environmental improvements, should be funded in lieu of the existing system. Past evaluations by the Metro District and consultants have indicated problems with groundwater contamination and excessive soil loadings at Lowry. Therefore, the Lowry system is evaluated further in this document, as well as in Volume II, Issue III-1.

The EPA guidelines recognize that the choice of a disposal method is not as important as properly evaluating the chosen method with respect to a wide range of environmental conditions. The EIS process functions to evaluate in detail any impacted environmental elements in order to insure the least environmental degradation. The guidelines indicate that for land recycling schemes the following elements must be considered:

1. Soils.
2. Groundwater.
3. Stabilization of sludge.
4. Sludge characteristics (heavy metals, nutrients).
5. Pathogen reduction.
6. Crop suitability.
7. Public access.
8. Surface runoff.
9. Application methods.
10. Application rates (nutrients and trace elements).
11. System operation control.
12. Monitoring.
13. Food chain considerations.

Thus, in the body of this Environmental Impact Statement, EPA considers in detail the following two sludge management systems.

1. Metro's proposed land recycling system using anaerobic digestion, pipeline transport, drying beds, storage and distribution to the land. Metro has proposed that dried sludge could be used on irrigated areas, dryland areas, sod farm operations, metropolitan Denver parks and reclamation of some mine spoil areas. It has also been suggested that dried sludge might be made available to individual home gardeners. Metro has also indicated the possibility that the sludge could be bagged and sold commercially.

Table 2. FINAL SLUDGE HANDLING ALTERNATIVES COMPARISON FOR METRO DENVER DISTRICT

Sludge handling alternative	Environmental impacts		Engineering factors		Institutional ability to implement	Costs	Overall[a] rating
	Beneficial	Adverse	Feasibility	Reliability			
			Disposal				
Land disposal **Landfill**	None	Groundwater leachate problems, soil stability, explosive gas production	High	High, but requires close control of deposition and must be mixed with dry solid waste and/or soil	High-existing, but would require new disposal sites	All disposal operations have no revenue, low capital costs and high operating, energy and chemical costs	Marginal
Landspreading	Can improve soil structure and add nutrients	Can harm soil quality by excessive metal loadings; can affect groundwater, food chain	High, but requires large land areas and constant monitoring	Moderate, requires standby system for winter and wet days	High-existing, but would require new landspreading sites	Low capital costs; moderate operating costs; high energy and chemical costs	Acceptable
Incineration--ash disposal	Minimal, material volume reduced	Releases particulates and gases to air; ash disposal can create leachate problems in groundwater; high energy utilization	Moderate, moisture content of sludge could affect operation	High, except air pollution control equipment may have problems	Moderate, because of air pollution problems	High capital and energy costs; moderate operating costs; chemical costs could be high	Marginal
			Recycling--Separately				
Land recycling **Air drying**	Improves soil structure; adds nutrients; minimizes energy use	Localized groundwater problems at drying site; pathogen problem; control of final use difficult	High, but requires complex coordination for recycling	High, except for occasional digester failure	High, except for farming community resistance to land se aesthetic deterioration	High capital costs and low operating, energy and chemical costs; high revenue likely	Most favorable
Composting	Improves soil moisture; high nutrient value; minimum energy use	Same as air-drying	Moderate, requires good market for recycled material	High, except for potential contaminants	Limited Metro experience or research in this area	Same as air-drying; revenue could be high, uncertain at this time	Favorable
Incineration **Drying--recycle**	Cattle feed; soil amendment	Odor problems; ash disposal; low intensive energy use	Low with past Metro experience; could be higher with anaerobic sludge	Low to moderate because of incinerator breakdowns	Low, Metro experience with drying unfavorable	Same as air-drying; revenue could be high, uncertain at this time	Acceptable

Ash-heat production	Produces useful heat	Disposal of ash and leachate to ground-water problems	Low as a separate system	Low	Moderate	High capital, operating energy and chemical costs; low revenues	Unacceptable
Conversion Pyrolysis	Useful carbon-black product	Heavy metal contaminants; releases gases	Experimental	Unknown	Low; untested	High capital, operating energy and chemical costs; revenue unknown	Unacceptable
Cattle feed	Valuable cattle feed supplement	Unknown, potential metal contaminants in food chain	Experimental	Unknown	Low; untested	Same as pyrolysis	Acceptable
			Combined Recycling with Municipal Solid Wastes				
Land recycle--composting	Large amounts of fertilizer and soil amendments	Control of pathogens difficult; odor problems	Probably high	High	Low; lack of legislative support for financing solid waste systems	Costs unknown to a great extent for all combined options	Marginal
Incineration—power production	Useful heat or steam energy produced in large amounts	Ash disposal; release of gases to air	Potentially high; water content in sludge lowers heat value; past operating problems with CO from incinerators	Probably high	Low; lack of legislative/financial support	Costs unknown, could be low for Metro	Marginal
Conversion Supplemental boiler fuel	Energy source for industrial use	Air pollution, ash residue	Very low, impractical with DRCOG proposal	Low	Low; lack of legislative/financial	Costs unknown, could be low for Metro	Unacceptable
Synthetic gas production	Synthetic natural gas for industrial/domestic use	Ash residue	Moderate, caloric and high water content of Metro sludge somewhat unfavorable	High, if sludge quality constant, but unknown reliability for overall system	Low; lack of legislative/financial support	Costs unknown, could be low for Metro	Acceptable

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[a] The overall rating scale (unacceptable, marginal, acceptable, favorable and most favorable) was developed through a semi-quantitative relative ranking and evaluation of the alternatives on the basis of parameters presented in this Table. The subjective nature of this method is shared by all such attempts at numerical evaluation.

2. Metro's existing disposal operation of landspreading and occasional burial at the Lowry Bombing Range. The system will be modified by the addition of anaerobic digesters at the Metro plant. Other possible modifications are also discussed.

The analysis of the alternative systems is prefaced in this Section by a discussion of the sub-system alternatives within each of the major alternatives.

SUB-SYSTEM ALTERNATIVES

Many environmental impacts can be lessened by careful attention to the design details of the chosen system. The National Environmental Policy Act requires that consideration be given to lessening environmental impact of a project by evaluation of alternatives and selection of an environmentally sound option and then by mitigation of negative impacts through careful attention to design details. This Section of the EIS discusses the basic components of the major alternatives, their environmental impacts and the means by which their impacts might be mitigated.

Sub-System Alternatives to the Metro Land Recycling Proposal

Stabilization--

Some form of sludge stabilization is necessary before sewage sludge can be applied to the land. Stabilization involves the destruction of volatile matter in the sludge. If sludge were applied to the land unstabilized, odiferous conditions would result.

The most commonly applied stabilization process is digestion, either aerobic or anaerobic. Based on many years experience with both digestion processes, Metro has selected the latter for this project, for the following reasons: (1) Anaerobic digestion is a well-established process in the sewage treatment technology field; it has very low energy use requirements, whereas aerobic digestion requires considerable energy to supply air to the mixed sludge, (2) The methane gas from anaerobic digestion can be used to power the digestion process and perhaps other units, and (3) Aerobic sludge must be very well digested in order to avoid odor problems, if the sludge becomes septic.

An issue within the general choice of anaerobic digestion is whether the process should be mesophilic (operating at temperatures between 21°C and 39°C [70°F and 103°F]), or thermophilic (operating between 40°C and 54°C [104°F and 130°F]). Thermophilic digestion results in a better stabilized sludge that can be more easily dewatered. Pathogen reductions are also reported to be more effective with this process. The principal negative aspects of thermophilic digestion are the high additional costs for insulation and extra heating. Metro has decided to operate the system in the mesophilic range.

The actual range of choice for the digestion sub-systems is extremely limited because EPA has already provided the Metro District with funds for anaerobic digesters. EPA intends to evaluate whether operation in the thermophilic range is desirable and within reasonable cost limits, given the present design of the anaerobic digesters. Such a study can be performed in a future research project.

Transportation--

The principal means of conveyance to a sludge drying/storage facility in the Metro proposal is by pipeline. Two pipes (25 and 30 cm [10 and 12 in.]) will carry the sludge, with a pumping station at the Central Plant and an intermediate pumping station. A preliminary design of the pipeline is available at the time of this writing, and is discussed in more detail in Volume II, Issue I-2. An earlier description of the pipeline design is given in Volume III of the facilities plan (Reference 55) and Section IV of this EIS. Generally, EPA has not had any outstanding conceptual problems with the pipeline design and, hence, no design alternatives are offered here at this time.

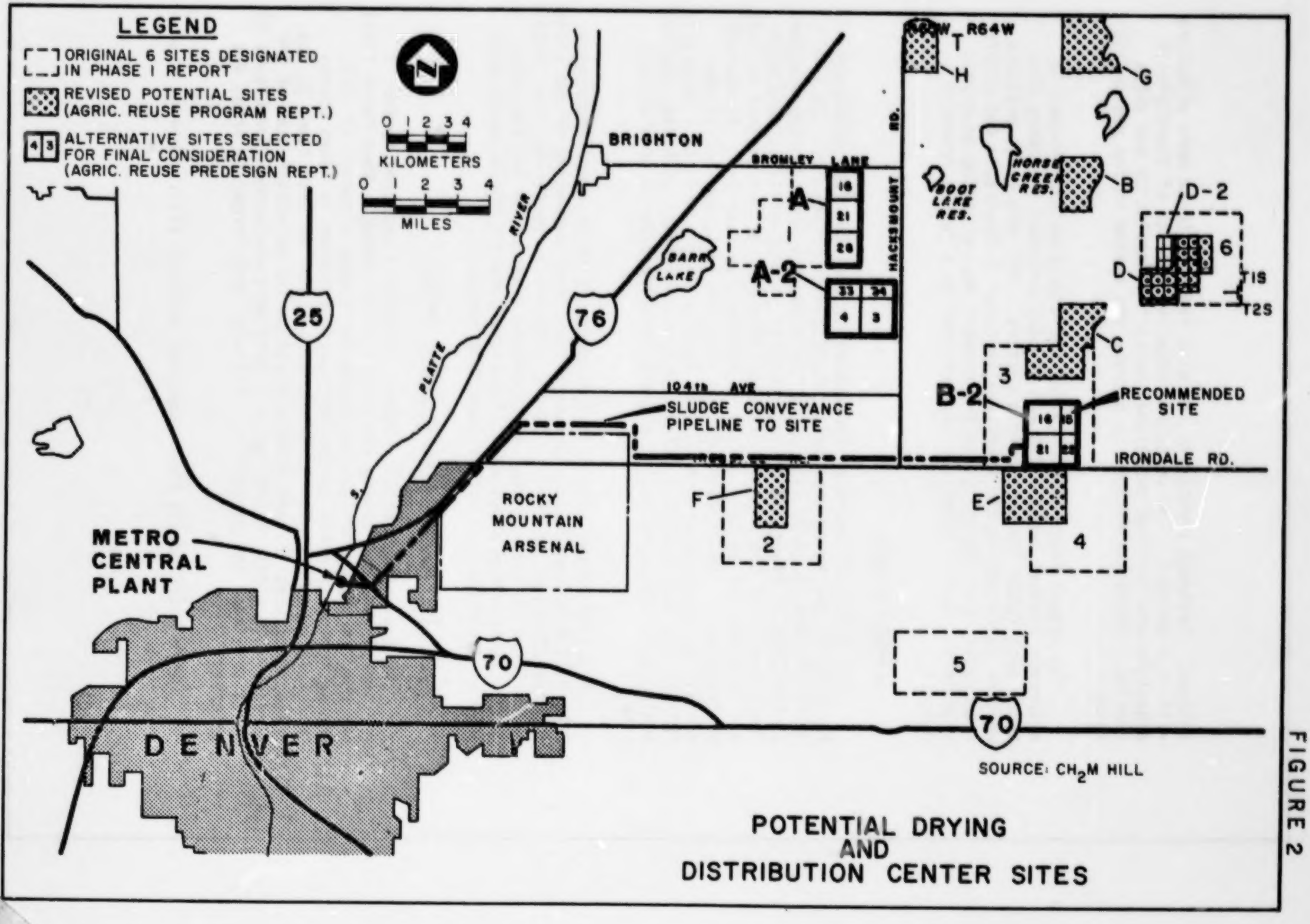
Pipeline routes were also considered to be of minor importance. CH2M-Hill considered two pipeline alternatives depending on the sites for the distribution center. Since Site B-2 is preferred, the route along Irondale Road is the corresponding alternative for the pipeline. Because the pipeline will follow roadway right-of-ways, minimum environmental or social impact is expected.

Sites for Drying and Distribution Center--

The most controversial element in Metro's proposed system is the location of the drying and distribution center. When Metro first proposed its spray irrigation system for sludge disposal in 1972, the agricultural areas to the northeast of Denver in Adams County were felt to be best for this type of system. At that time, it was anticipated that dryland farming would be the principal user of the sludge. Six sites in this general area were evaluated (See Figure 2) and a site near the present B-2, although much larger in area, was selected.

Metro modified its land recycling proposal after meetings with

FIGURE 2


LEGEND
ORIGINAL 6 SITES DESIGNATED IN PHASE I REPORT
REVISED POTENTIAL SITES (AGRIC. REUSE PROGRAM REPT.)
ALTERNATIVE SITES SELECTED FOR FINAL CONSIDERATION (AGRIC. REUSE PREDESIGN REPT.)
N
0 1 2 3 4
KILOMETERS
0 1 2 3 4
MILES
BRIGHTON
BROMLEY LANE
HACKSMOUNT RD.
R65W R64W
T
H
G
B
HORSE CREEK RES.
BOOT LAKE RES.
BARR LAKE
A
A-2
16
21
28
33
34
4
3
D-2
D
6
T1S
T2S
C
3
B-2
RECOMMENDED SITE
16
15
21
22
IRONDALE RD.
104th AVE
SLUDGE CONVEYANCE PIPELINE TO SITE
25
76
RIVER
PLATTE
ROCKY MOUNTAIN ARSENAL
F
2
E
4
METRO CENTRAL PLANT
70
5
70
DENVER

SOURCE: CH_2M HILL

POTENTIAL DRYING
AND
DISTRIBUTION CENTER SITES

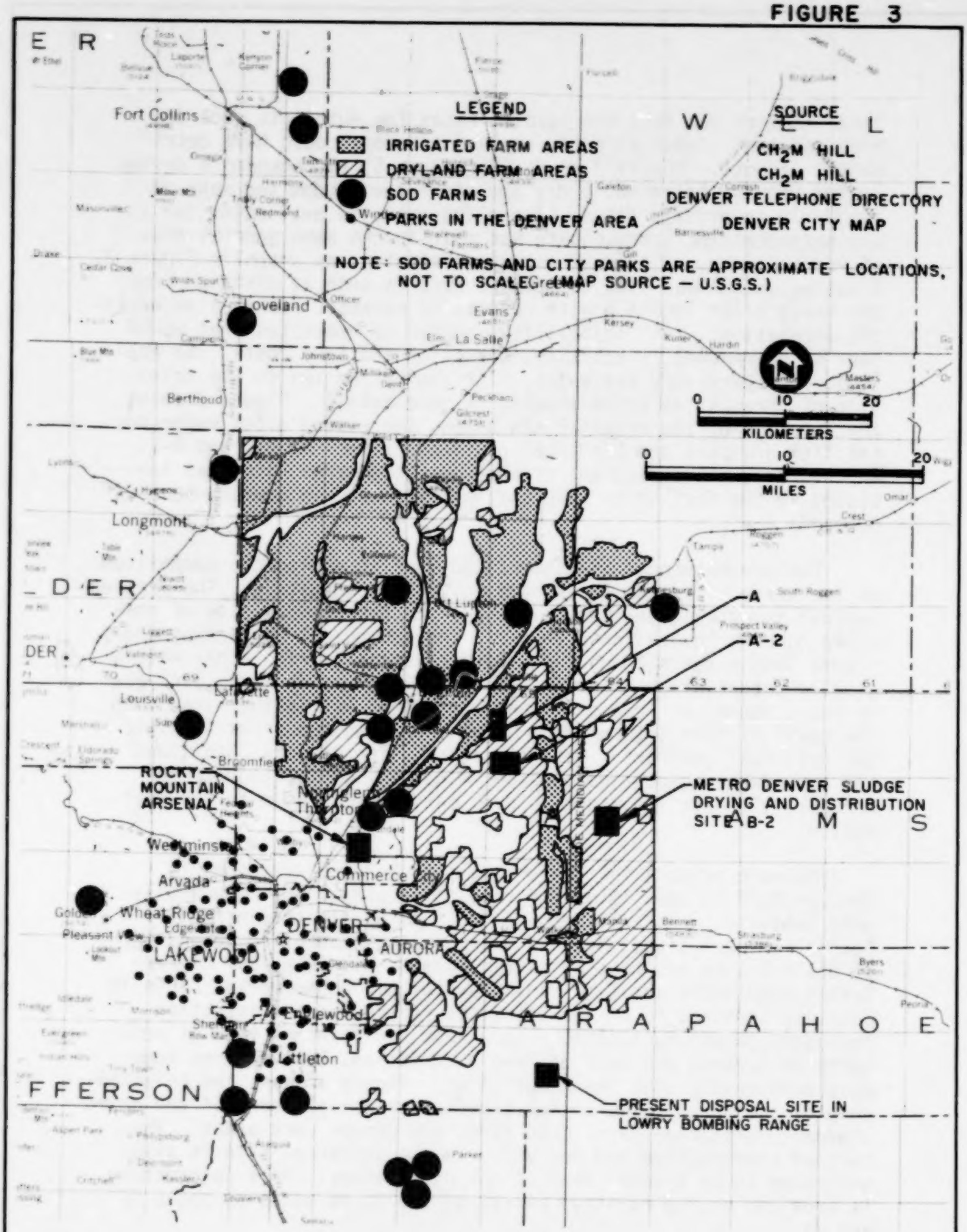
local farmers who felt the loading rates for nutrients were too high and that sludge directly applied to crops could have detrimental effects. The 1973 study (Reference 5) recommended a drying system whereby Metro would dry and store the sludge and make it available to private farms. A preliminary site evaluation for a drying/processing/storage site was made in the same general area of Adams County. Eleven sites were evaluated, as shown in Figure 2. A rating system was used to compare factors such as distance from the Metro plant location with respect to markets, nearness to existing populations, soil suitability, number of homesites that would have to be removed, visibility, elevation and land costs. No ecological factors were evaluated. The evaluation led to the selection of three sites to be studied in more detail. Figure 2 shows the location of the original six sites, the eleven sites under the modified proposal and the three preferred sites--A, A-2 and B-2. An environmental assessment of the three preferred sites was included in the facilities plan and is reproduced in summary here in Appendix G.

The environmental assessment included an ecological comparison of the three sites and an archaeological investigation. The archaeological investigation identified only one prehistoric site of possible concern located on site A-2. The ecological evaluation concluded that sites A-2 and B-2 were floristically rich areas with a greater potential as wildlife habitat. This was in large part due to the presence of "relictual prairie areas" within the sites. On the basis of this information, Metro redefined the sites to avoid the relictual prairies. Detailed information on soil conditions and groundwater depth and quality is not available; thus these factors, although important, played only a minor role in the evaluation.

Metro's reasons for preferring site B-2 are described in Chapter 6 of Volume III of the facilities plan. Environmentally, only land-use considerations were felt to be significantly different for each site. Metro's overwhelming reason for selection of the B-2 site was to stay as far away as possible from concentrated population areas to avoid any further controversy. This is candidly admitted to be the principal reason for the selection indicated in the facilities plan. From the point of view of proximity to markets and ease of land acquisition, B-2 compares somewhat unfavorably with the other sites. Figure 3 shows the relationship of the three sites to the expected principal users of the dried sludge: irrigation farms, sod farms and Denver park areas. The cost of construction and operation at the preferred site is also estimated to be greater than at the other sites. More information is provided on the relative merits of the three sites on pages 92 and 93.

On 8 May 1975, EPA, recognizing the controversial nature of

FIGURE 3


LEGEND
SOURCE
▩ IRRIGATED FARM AREAS — CH2M HILL
▨ DRYLAND FARM AREAS — CH2M HILL
● SOD FARMS — DENVER TELEPHONE DIRECTORY
• PARKS IN THE DENVER AREA — DENVER CITY MAP
NOTE: SOD FARMS AND CITY PARKS ARE APPROXIMATE LOCATIONS, NOT TO SCALE. (MAP SOURCE — U.S.G.S.)
N
0
10
20
KILOMETERS
0
10
20
MILES
A
A-2
ROCKY MOUNTAIN ARSENAL
METRO DENVER SLUDGE DRYING AND DISTRIBUTION SITE B-2
PRESENT DISPOSAL SITE IN LOWRY BOMBING RANGE
Fort Collins
Loveland
Berthoud
Longmont
Louisville
Broomfield
Westminster
Arvada
Wheat Ridge
Golden
Pleasant View
Edgewater
LAKEWOOD
DENVER
AURORA
Commerce City
Northglenn
Thornton
Englewood
Sheridan
Littleton
Evans
La Salle
Lafayette
E R
W E L L
DER
A D A M S
A R A P A H O E
FFERSON

IRRIGATED AND DRYLAND FARMS, SOD FARMS AND PARKS OF THE DENVER AREA IN RELATION TO THE SLUDGE DISTRIBUTION SITE

site selection, requested that the Metro District Board of Directors refrain from any actions to acquire the B-2 site until the National Environmental Policy Act process was completed. EPA feels that the work done to date by the District and CH2M-Hill represents a reasonable effort at evaluating the sites considered so far; however, it is necessary to evaluate a wider range of sites, which have been suggested by others. For example, suggestions have been made to use the Rocky Mountain Arsenal or the Lowry Bombing Range as a drying/distribution site. The facilities plan did not discuss these possibilities. Others have expressed a desire to know why the site could not be located further north in Weld County or further to the southeast in the vicinity of Lowry Bombing Range.

The Metro District has indicated to EPA that the Defense Department is opposed to any use of the Arsenal site for a sludge drying/distribution center. At this point, it would be difficult to say how favorable or unfavorable the Arsenal would be from a soils or groundwater standpoint. It is likely that unless the Defense Department has developed a definite plan for the long-range use of this facility, it would be reluctant to provide a portion of the Arsenal on a piecemeal basis. The site does contain significant wildlife and natural areas; it also contains sites where very toxic materials are stored. It has recently been indicated that the Army will have to exhaustively search any part of the Arsenal that becomes open to public access for stored poisons or weapons. The Army Department also informed Metro that no Arsenal land could be used until the nerve gas detoxification program is completed in 1977.

The Lowry Bombing Range would seem to be an ideal site for the proposed sludge drying and distribution operation since Metro has already been operating there. However, the pipeline would have to traverse a developed urban area with a consequent increase in cost and inconvenience. A second consideration is that the elevation of the Lowry site is about 150 m [500 ft] higher than the B-2 site which would approximately double the pumping costs. In addition to the above disadvantages, there is a rapidly developing urban fringe in the southeastern Denver area within eight km [five miles] of the site, which may cause a future land-use conflict. There are also institutional problems in acquiring the site. Finally, the site is remote from most potential markets, as shown on Figure 3.

The principal way to avoid some of these conflicts is to obtain some part of the Lowry Bombing Range that would not involve population conflicts. The institutional arrangement at present does not allow an easy transfer of land within the range. Metro District utilizes a portion of the bombing range that has been leased to the City and County of Denver from the U.S. Government. Again, it is premature to develop any detailed comparison of the benefits and costs of this site unless indications could be obtained from the Defense Department that such land could potentially become available. Were this the case, environmental and engineering information would be required to evaluate the merits of sites in the general vicinity. Finally, it would appear that the site would be located at some distance from its potential markets, especially irrigated farms. However, some sod farms and Denver parks would perhaps be somewhat closer than with the B-2 site. A more systematic comparison of the preferred site, B-2 and Lowry, is found in Volume II, Issue IV-1.

Lands to the north and west of the Platte River would generally be unfavorable because of their proximity to populated areas. Weld County has already indicated a lack of interest in having the Metro District locate their sludge distribution center within the county. However, the presence of large amounts of irrigable lands and sod farms makes this area attractive from a potential market standpoint. Lands lie at lower elevations in this general direction and would result in lower pumping costs; land values are higher, however, and would increase the capital costs of the project. Additional discussions of site alternatives are presented in Volume II, Issue IV-1.

The principal conclusions of EPA at this time with regard to site locations would still be the following:

1. There appears to be no site that is overwhelmingly superior from an overall standpoint.
2. It is generally true (at least in the predominantly dryland areas selected for site consideration) that there are no significant environmental issues involving vegetation or wildlife areas that could not be avoided.
3. There is enough specific soils and groundwater data in the principal sites considered to indicate the beneficial and adverse impacts of locating there.
4. Cost differentials between sites considered are small. The cost implications of some of the suggested sites are unknown.
5. A potential health risk may be associated with actual physical contact with the sludge. However, no significant health risk exists as a result of the presence of members of the public living, working or merely visiting within the environs of the sludge drying and distribution center as long as appropriate precautions are observed.
6. No matter which site is selected, there will be public controversy about the location of a facility of this kind. A possible exception could be one of the two Federal areas--Lowry or the Arsenal. However, it does not appear that these areas will be available.
7. Selection of an area that is reasonably close to market areas could be important if trucking and sludge distribution costs are high. However, with the range of potential uses suggested for the dried

sludge--from sod farms to parklands--and with no definite information about the preponderant users of the sludge, the optimal location of the site from this viewpoint is impossible to determine at this point.

On the basis of information available to EPA, site B-2 is accepted by EPA as a "reasonable" site for sludge drying operations. EPA feels that the principle which was advanced in the discussion of overall alternatives pertains here as well: once a "reasonable" choice is made, it may be more important to evaluate a given site in detail and suggest design features to minimize effects on the natural and human environment, rather than try to select an optimum site. Those factors which could be important from a locational standpoint--distance from market, soils, groundwater conditions--while they may differ from a cost and environmental standpoint, are not significant enough to warrant a change of site. The reasons for this conclusion are found in the discussion under Issue II-1, Volume II.

Drying Basin Design Alternatives--

Although there are a variety of design alternatives that could be of potential interest, only one at this point has been identified as an environmental issue: control of percolation waters from the drying sludge that could result in groundwater contamination.

At present, Metro is planning to take the supernatant from anaerobic digestion that is usually treated at the wastewater treatment plant to the drying site. In order to pump sludge the distance called for in this plan, a sludge of two to three percent solids is necessary. This involves the use of some of the supernatant which normally runs at about one percent solids. There is an agricultural advantage to pumping the supernatant with the sludge, since it contains considerable amounts of nitrogen and phosphorus.

A difficulty occurs when the sludge is applied to the drying basins. With the sludge in a liquid form, most of the free water could percolate downward toward the water table. Some water will be lost to evaporation and some will stay in the dried sludge, but most will move downward where it will likely result in degradation of water quality to a degree that would make the groundwater unacceptable as a source of drinking water. High nitrate concentrations in drinking water can cause infant methemoglobinemia. High concentrations of dissolved solids will deteriorate groundwater quality for both potable use and irrigation.

Nitrate concentrations in the percolating water may be reduced by bacterial denitrification, a process that occurs under anaerobic or least depressed dissolved oxygen conditions. It is not known to what degree the process might occur in the drying basins.

Metro believed that the likelihood of groundwater contamination is low and proposes to monitor groundwater quality in order to rapidly detect any deterioration. If deterioration occurs, Metro would install a system to collect and treat percolating waters. Alternatively, the drying basins could be lined. EPA will require lining of the drying basins to minimize leaching to the groundwater reservoir (see discussion in Volume II, Issue II-2).

Alternative Design Capacities--

The presently proposed system is designed to handle the sludge loads from the Metro system projected to occur in 1985. The facilities plan indicates that the sludge loads will increase from 30,000 dry metric tons [33,000 tons] in 1974 to 55,000 dry metric tons [61,000 tons] per year in the early 1980's. These sludge quantities are proportional to the wastewater flow volumes to be treated at the Metro central (and possibly satellite plant) facilities.

EPA has become sensitive to the possible secondary impact of funding large excess capacities for utilities such as sewage treatment facilities. The issue becomes especially critical in air quality priority areas such as Denver where water quality benefits obtained from providing treatment to future residents conflict with the additional air quality degradation from the automotive habits of these newer residents. EPA has funded a Section 208 study under the Federal Water Pollution Control Act Amendments of 1972 that will evaluate and guide population projections of facilities plans in the Denver area. The designated planning agency is the Denver Regional Council of Governments(DRCOG). At present, DRCOG has been working with facilities planners to reduce the somewhat inflated earlier individual Districts' population projections, to conform with the planned growth figure of 2.35 million persons in the overall Metro area by the year 2000. The latter goal has been adopted by the DRCOG and approved by its members.

EPA recognizes that concern of local farmers that more land may be needed in the future if present sizing of facilities proves to be inadequate.

The sludge loads projected by the Metro District and its facilities planning consultant were developed as far back as the 1972 predesign study. The values presented in Volume III of the facilities plan (Reference 55) on page 4-1 are essentially unchanged from earlier projections. The annual rate of population growth and hence growth in sludge loads is estimated to be at

5.5 percent per annum over the 1975-1985 period. While this rate did occur in the early seventies, current growth rates in the metropolitan area are much closer to the recommended DRCOG growth rates of 2 to 2.5 percent per annum. Thus it appears that at least the amount of excess capacity designed into the sludge handling system may be beyond that necessary to support the aqueous stream treatment facilities sized on the basis of the lower population projections. The capacity of the drying bed design is more thoroughly evaluated in Volume II. Issues II-12 and II-13.

There appears to be little direct correlation between the addition of sludge handling capacity and induced growth. That is to say, additional capacity will not in itself induce individuals to settle in the metropolitan Denver area. However, EPA has generally tried to coordinate its planning efforts for wastewater facilities with other plans in a given area for consistency. Because additional capacity accommodates additional growth, it can still contribute toward excessive growth that may be inconsistent with other planning efforts. In this case, the planning involves EPA's own responsibilities under the Clean Air Act. This issue has been dealt with in more detail in the Denver Regional Overview EIS.

"Excessive" capacity is also exceptionally difficult to define in the case of the design of this project. The only 'average' figures available for design purposes are the projected sludge loads. Design values for most of the equipment are based on peak flows that vary with the particular unit. Anaerobic digestion equipment is already under construction and therefore not really an issue. Pipeline sizing and pump sizing is based on peak flows for limited time periods. These can be related to an average flow, but sizing requirements are not very sensitive to average changes. The basin sizing is a function of the amounts of sludge and wastewater to be dried, but two constraints apply. First, an average value of wet sludge, about three percent solids, is assumed, but a change in consistency to say 2.5 percent solids might be more important than the actual solids amounts involved. Secondly, the actual time needed for drying in the basins is not precisely known. A year's time is assumed for design purposes, but longer or shorter drying times might be needed. Construction of basin volume can be staged to meet needs as demonstrated in the early years of the project. However, due to inflated costs associated with later development, Metro District currently plans to develop the entire 240 hectares (600 acres) at this time.

The principal alternative to the present sizing may be to limit the monies spent on the drying/storage system. From the point of view of secondary impacts, since control of the size of aqueous stream treatment facilities will accomplish control of the rate of wastewater utility growth, control for sludge management facilities may not be necessary.

Sub-System Alternatives to the Present Lowry Disposal System

In a sense, sub-system alternatives to a null alternative are a contradiction in terms. However, the null alternative may be improved by certain changes which can be regarded as mitigation measures or sub-alternatives. This may be important because, although the proposed system appears most advantageous, some modified version of the existing system is the most likely option in the event that the proposed system proves infeasible.

Variations to the present Lowry system presented here are tentative; they have had neither the benefit of a cost evaluation nor an engineering and environmental evaluation. EPA simply suggests these alternatives at this time as somewhat less preferable alternatives that may have to be evaluated in more detail if funding is not available for the more capital-intensive land recycling system now proposed by Metro. In the interim, some form of land recycling system may be used if the sludge drying project is delayed. Metro has stated that incineration would be the preferred sludge disposal system if the sludge drying project is delayed.

Sludge Conditioning and Digestion--

It has already been mentioned that Metro has received a Federal grant to construct facilities at the Central Plant to anaerobically digest all Metro sludges. Part of the problem at the Lowry site has been the deposition of large amounts of unstabilized sludge containing large quantities of chemicals used for conditioning. These chemicals include ferric chloride, lime and polymers. While they have not been considered to be deleterious to the soil, it would be preferable to keep them out of the sludge if possible.

The performance of anaerobic digesters on the raw and waste activated sludges now treated at Metro must be considered an unknown area at present. Anaerobic digestion can improve the dewatering characteristics of sludges (resulting in less chemicals for conditioning). However, digestion of secondary waste activated sludge may not perform in the same fashion. It might be expected that odor and chemical-related problems at the Lowry site will be reduced by the measures already under construction. Conversion of the digestors to the thermophilic mode might further improve sludge dewatering characteristics.

Transport--

CH2M-Hill indicated in its evaluation of the present alternative that it might become more economical for Metro to purchase its own fleet of trucks to haul sludge to Lowry; Metro recently did this. A pipeline would have been a reasonable alternative only if Metro had been guaranteed long-term use of the Lowry site, which was not the case.

The Lowry Site--

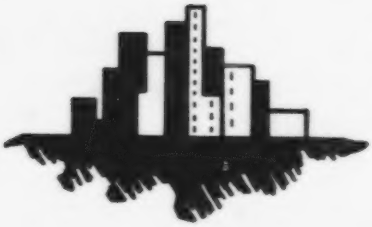
As discussed previously, use of the Lowry Bombing Range is contingent upon City and County of Denver approval or possibly through obtaining a long-term lease for some part of the bombing range. The present operation is predominantly a landspreading operation where sludge is being loaded onto the land at annual rates considered highly excessive for good sludge recycling practices on dryland. As long as the area involved is small, the use of a "sacrifice area" is reasonable. Denver plans to eventually use this area as a landfill. Some plant species, including wheat, will grow on the site even with the high loading rates. The sacrifice would generally be in the potential contamination of surface water supplies and food chain hazards posed by grazing animals. A modification might involve restriction of grazing animals from direct contact with sludge-amended areas.

If grazing were to be permitted but controlled, additional forage growth might be provided for cattle. This could be expensive for Metro since large land areas would be involved. The fact that many separate owners are involved would make acquisition of large areas of the bombing range difficult.

A second alternative might be to develop some modified type of drying/windrowing operation to store anaerobically digested-vacuum filtered sludge at Lowry for sale or distribution to local farmers, sod farms, etc. This would involve a substantial change of the use of the bombing range that would need approval by the local managers. The alternative suggested here differs from the site alternative consideration for the Metro proposed system in that minimal capital investment for new facilities would be required. Metro could store some sludge and landspread the remainder until a market developed. Such a system would need large amounts of land available in order to remain flexible. The operating costs for such a system would remain high since vacuum filters and truck hauling (the largest part of present operation costs) would still be required. The key to success of such an alternative is the economical dewatering of the bulk of Metro's sludge (secondary waste-activated sludge). Tests by Metro indicate that this sludge does not dewater well after anaerobic digestion.

33.a

SECTION III



This section contains a description of the general setting for the project. The environmental and social areas covered are ones that might reasonably be expected to affect or be affected by this project or its alternatives.

Because sludge applications could occur almost anywhere in the Metropolitan Denver area, it is necessary to broaden the focus of study to include the overall environment. EPA is particularly concerned about impacts that could occur after the sludge has left the drying and distribution site and is finally applied to the land. Therefore, the environmental settings for actual use sites (Denver parkland, sod farms, minespoil reclamation sites, irrigated and dryland farms) are described to the extent that there are recognizable differences in the way the impacts might occur at different sites and with different uses of the land. These site-specific descriptions are found in Appendix E, which also contains a description of the Lowry Bombing range since that site is considered a basic alternative to the project proposed.

SECTION III

ENVIRONMENTAL SETTING

The study area is comprised of several sites, which are highly diverse in natural and artificial characteristics. The service area of the wastewater management system and the City parks are in a highly urbanized setting; most of the proposed sludge reuse sites are rural, and the mine spoil reclamation sites are extremely remote and isolated from public access. While most potential land application sites are within 50 km [30 miles] of the proposed sludge drying and distribution site and to the east of the site, the mines are generally much farther away, to the west.

The environmental setting for the proposed action comprises the entire Denver region. The general discussion of the region in this Section is supplemented in Appendix E by descriptions of environmental settings in five specific sites, providing examples of possible agricultural reuses of anaerobically digested, air-dried sludge. For each category of reuse potential, a representative site was selected--mainly by virtue of the interest expressed by the owner and/or operator of the site in the use of sludge in the operation--for detailed investigation of the environmental setting and the probable impacts.

The representative sites serve to pinpoint the impacts which can be expected from sludge application to all areas of similar characteristics. For those areas which have very different characteristics, the impacts may vary widely. Therefore, it is important that, prior to drawing generalizations from assessments made here, one compare the environmental characteristics of the proposed sites with those of the representative sites. Clearly, some extrapolations and approximations will be possible in many cases; but, in some cases, it may be necessary to reevaluate the impacts and adjust application rates and management conditions to match the requirements of the particular site.

A discussion of the environmental setting at the Lowry Bombing Range sludge disposal area is presented, also in Appendix E, to serve as a basis for the evaluation of impacts of the "no-action," present alternative.

CLIMATE

The Metropolitan Denver region, lying on the western edge of the Great Plains, near the foothills of the Rocky Mountains, is an area of transition from the climate of the plains to the climate of the foothills. The region has a high-elevation continental climate that has been characterized as semi-arid, Steppe-type clime (Reference 9).

Temperature

Temperatures are generally moderate, with a mean annual temperature of 11.3°C [52.3°F]. Ranges in extremes have been recorded from -34°C [-30°F] to 40°C [105°F]. Mean monthly temperatures for Denver are presented in Table 3.

Precipitation

Monthly precipitation data for Denver are shown in Table 3. Generalized precipitation patterns for the Denver region and surrounding areas are shown in Figure 4. Precipitation is relatively light (average annual depth: 31 cm [12 in.]), with a large proportion of the rain falling during the growing season from April to September. Much of this summer precipitation occurs as a result of thunderstorm activity. Table 4 shows the seasonal occurrence of thunderstorms. Heavy thunderstorms in the eastern foothills and plains area occasionally cause damaging flash floods. Maximum expected precipitation frequencies as flood-producing events are also shown in Table 4, together with relative humidity data. The generally low relative humidity is a major factor in the areal potential evapotranspiration rate of 610 mm [24 in.] per year (Reference 9). This amount is twice the average precipitation and is an indication of the aridity of the area. Periods of drought one to two years in length are fairly common in portions of Adams County (Reference 10).

Snowfall is generally not heavy, with most snow occurring between November and April. Mean monthly snowfall data for Denver are shown in Table 3. Extensive flooding caused by snowmelt in the mountains occurs only at times when there has been either a heavy accumulation of snow or a sudden increase in high-elevation temperatures (Reference 11). The growing season is approximately five to six months long, from April to September, when the temperature does not fall below freezing.

Wind

Wind data for the Denver airport are presented in Table 5.

Table 3. TEMPERATURE, PRECIPITATION, SNOW AND FREEZE DATA, DENVER (WB CITY)

Mean	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature													
°C	1.2	1.8	3.6	8.8	14.7	20.8	23.6	22.9	18.4	12.1	4.7	2.6	11.3
[°F]	34.1	35.3	38.5	47.8	58.4	69.4	74.5	73.2	65.1	53.7	40.5	36.6	52.3
Precipitation													
mm	8.6	16.3	20.6	36.8	65.0	25.9	37.3	30.5	19.3	24.4	14.2	10.7	309.6
[in.]	0.34	0.64	0.81	1.45	2.56	1.02	1.47	1.20	0.76	0.96	0.56	0.42	12.19
Snowfall													
cm	15.7	23.6	29.7	27.2	3.0	0.3	T	T	3.3	8.1	17.5	17.0	145.5
[in.]	6.2	9.3	11.7	10.7	1.2	0.1	T	T	1.3	3.2	6.9	6.7	57.3
Freeze													
No. days with temperature ≤ 0°C [32°F]	25	22	21	10	1	+[a]	0	0	+	5	18	24	126

Freeze threshold temperature °C	[°F]	Mean number of days between date of last spring occurrence and first fall occurrence
0	[32]	166
-2.2	[28]	192
-4.4	[24]	212
-6.7	[20]	231
-8.9	[16]	239

[a] + = 0 > .5

Source: Decennial Census of United States Climate.

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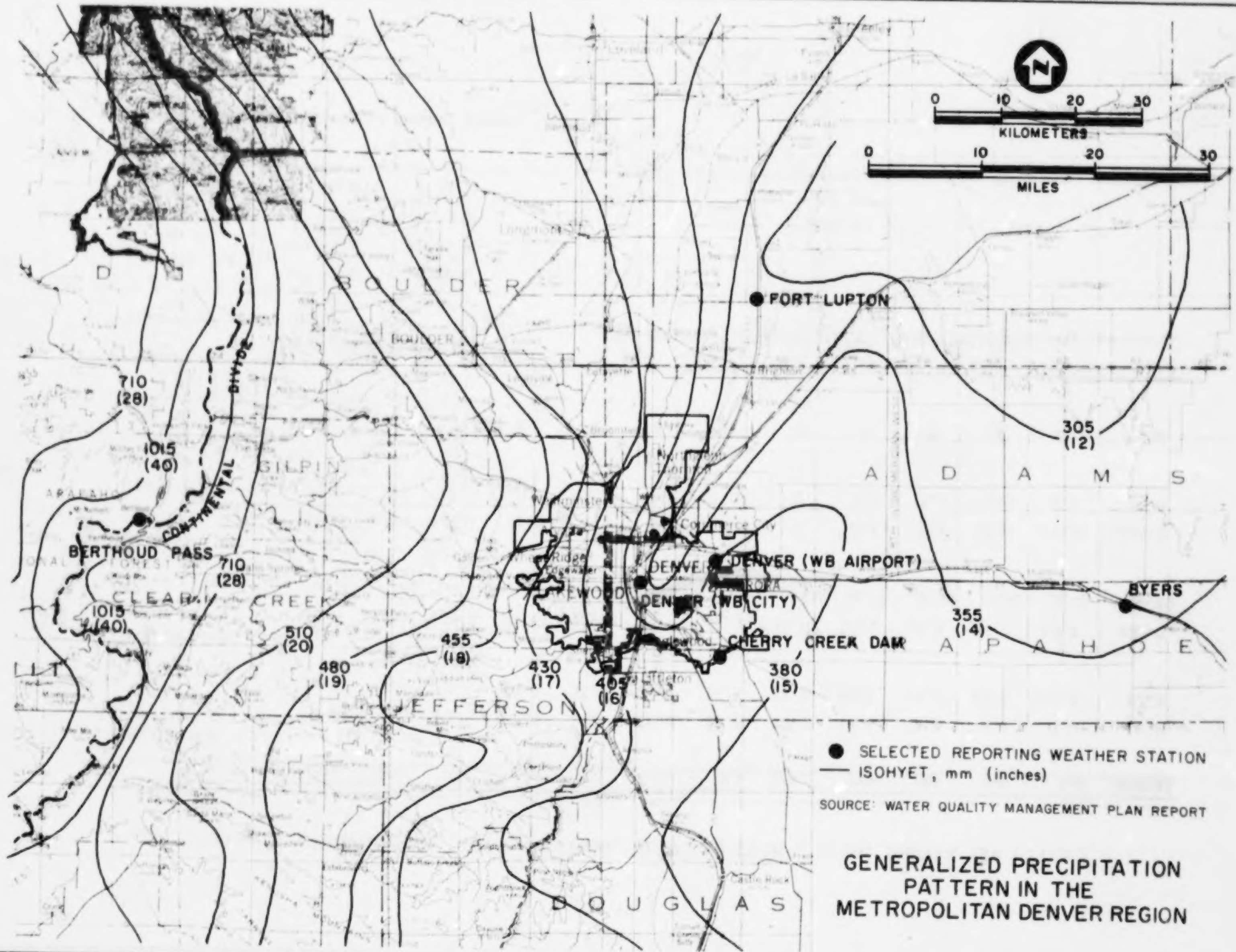
FIGURE 4


N
0 10 20 30
KILOMETERS
0 10 20 30
MILES
BOULDER
GILPIN
CLEAR CREEK
JEFFERSON
DOUGLAS
ADAMS
ARAPAHOE
CONTINENTAL DIVIDE
BERTHOUD PASS
FORT LUPTON
DENVER (WB AIRPORT)
DENVER (WB CITY)
CHERRY CREEK DAM
BYERS
DENVER
LAKEWOOD
AURORA
710 (28)
1015 (40)
710 (28)
1015 (40)
510 (20)
480 (19)
455 (18)
430 (17)
405 (16)
380 (15)
355 (14)
305 (12)
● SELECTED REPORTING WEATHER STATION
— ISOHYET, mm (inches)

SOURCE: WATER QUALITY MANAGEMENT PLAN REPORT

GENERALIZED PRECIPITATION
PATTERN IN THE
METROPOLITAN DENVER REGION

Table 4. MAXIMUM PRECIPITATION FREQUENCY, THUNDERSTORM AND RELATIVE HUMIDITY DATA, DENVER

Maximum amounts of precipitation to be expected within different time periods (frequencies)

Frequency, years	6-hour total		24-hour total	
	mm	[in.]	mm	[in.]
2	36 to 41	[1.4 to 1.6]	46 to 56	[1.8 to 2.2]
5	46 to 51	[1.8 to 2.0]	61 to 71	[2.4 to 2.8]
10	56 to 64	[2.2 to 2.5]	66 to 86	[2.6 to 3.4]
25	71 to 76	[2.8 to 3.0]	86 to 97	[3.4 to 3.8]
50	76 to 86	[3.0 to 3.4]	97 to 117	[3.8 to 4.6]
100	86 to 97	[3.4 to 3.8]	107 to 127	[4.2 to 5.0]

Thunderstorms, mean number of days

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
0	+[a]	+	1	6	10	12	8	4	1	+	0	43

Relative humidity

percent	percent of time
0 to 29	27
30 to 49	28
50 to 69	23
70 to 79	10
80 to 89	9
90 to 100	4

[a] The symbol + indicates a range between 0 and .5.

Source: Water Quality Management Plan, Denver Regional Council of Governments.

Table 5. WIND DATA, DENVER (WB AIRPORT)

Wind speed	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual mean
Mean hourly speed													
mps	4.3	4.5	4.8	4.7	4.4	4.4	4.0	3.7	3.7	3.8	4.3	4.5	4.2
[mph]	9.6	10.1	10.7	10.6	9.9	9.8	9.0	8.3	8.3	8.5	9.7	10.0	9.5
Prevailing direction	S	S	S	S	S	S	S	S	S	S	S	S	S
Fastest speed													
mps	18	22	24	23	19	21	20	18	21	18	18	23	24
[mph]	41	49	53	52	43	47	44	40	47	40	40	51	53
Direction	NW	NW	NW	SE	NW	S	SE	SW	NW	SW	NE	NE	NW
Frequencies of wind speed	percent												
0 – 1 mps [0 – 3 mph]	9.6	9.2	8.6	8.0	9.1	9.8	11.6	14.3	13.1	13.4	10.1	10.2	10.6
2 – 3 mps [4 – 7 mph]	25.6	25.1	23.2	23.5	24.8	25.2	28.2	27.6	30.4	33.5	26.9	25.8	25.7
4 – 5 mps [8 – 12 mph]	34.4	33.0	33.5	31.4	33.4	34.0	35.4	35.6	34.1	33.0	33.6	34.2	
6 – 7 mps [13 – 18 mph]	24.2	24.1	22.7	24.3	24.2	23.0	20.5	19.3	18.9	16.6	23.1	22.2	
8 – 10 mps [19 – 24 mph]	4.6	5.8	7.0	7.9	6.3	3.4	2.6	2.9	2.9	2.7	4.4	5.2	
11 – 13 mps [25 – 31 mph]	1.4	2.4	3.6	3.9	1.6	1.5	0.8	0.7	0.6	0.6	1.4	1.8	
14 – 16 mps [32 – 38 mph]	0.2	0.4	1.1	0.7	0.4	0.3	0.1	+[a]	0.1	0.3	0.4	0.5	
17 – 20 mps [39 – 46 mph]	0	+	0.2	0.2	+	+	+	0	0	0.1	+	0.2	
≥ 21 mps [≥ 47 mph]	0	0	0	+	0	0	+	0	0	0	0	0	

[a] + = < 0.5 percent.

Source: Water Quality Management Plan, Denver Regional Council of Governments.

Air quality is adversely affected by low wind speeds and special atmospheric gradients. Air pollution in Denver can occur when wind speed is 1 mps [3 mph] or less. A wind blowing at 2 mps [4 mph] will usually clear polluted air out of the city in about two hours (Reference 9). At the airport (see Table 5), wind speeds of 1 mps [3 mph] or less occur 10.6 percent of the time; winds blowing at 3 mps [7 mph] or less occur 36.3 percent of the time.

Chinook winds periodically blow from the mountains with great turbulence. This phenomenon results from high-elevation westerly winds being warmed in their rapid descent through a shallow layer of cool air covering the plains. Sudden rises in temperature accompanying these gusty winds exert a moderating influence on winter temperatures.

Regional Climatic Variations

Additional climatic data are presented for the six weather stations whose locations are shown in Figure 4. Climatological data for the city of Denver was presented previously in Table 3. Information from this table is applicable to the city's parks. Data provided by the Denver Airport and Fort Lupton weather stations (Table 6) are applicable to sod farms, irrigated farms and dryland farms. The Cherry Creek Dam and Byers weather stations (Table 7) are at the western and eastern extremes, respectively, of the Lowry Bombing Range. Data from these stations also pertain to some of the sod farms south of the Denver Metropolitan Area. These five weather stations fall within the Denver region, an area that is generally uniform climatically, although there are some local variations.

The sixth selected weather station, at Berthoud Pass, is located on the crest of the Continental Divide and experiences a different climate altogether. Discussion is deferred to a separate heading under Mine Spoil Site in Appendix E, as data from this station are applicable to that area only.

TOPOGRAPHY

The Metropolitan Denver region is located along the western periphery of the high plains of Colorado, which slope gently upward for almost 300 km [186 miles] from the eastern border of the state to the base of the foothills of the Rocky Mountains. The relief can be characterized as rolling prairie, with some hills and ridges intersected by nearly flat floodplains along watercourses. Much of the land currently under cultivation, mostly to the east and northeast of Denver, is nearly flat and level. Most of the land in Adams and Arapahoe counties has a slope equal to or less

Table 6. TEMPERATURE, PRECIPITATION, SNOW AND FREEZE DATA, DENVER (WB AIRPORT) AND FORT LUPTON

Mean	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature													
Denver AP													
°C	-0.3	0.7	2.9	8.1	14.1	20.2	23.1	22.3	17.8	11.3	3.7	0.9	10.4
[°F]	31.5	33.3	37.3	46.6	57.4	68.3	73.5	72.2	64.0	52.4	38.6	33.7	50.7
Ft. Lupton													
°C	-1.2	-0.3	3.1	9.3	14.9	20.5	23.4	22.2	17.6	10.9	3.1	-0.2	10.3
[°F]	29.8	31.4	37.5	48.8	58.8	68.9	74.1	72.0	63.6	51.7	37.5	31.6	50.5
Precipitation													
Denver AP													
mm	13.0	23.4	34.5	45.5	77.0	25.4	50.8	39.1	23.6	29.7	20.3	14.7	397.0
[in.]	0.51	0.92	1.36	1.79	3.03	1.00	2.00	1.54	0.93	1.17	0.80	0.58	15.63
Ft. Lupton													
mm	12.2	14.5	23.4	26.7	54.1	16.8	32.5	36.6	23.6	24.6	11.4	10.7	287.0
[in.]	0.48	0.57	0.92	1.05	2.13	0.66	1.28	1.44	0.93	0.97	0.45	0.42	11.30
Snowfall													
Denver AP													
cm	19.8	27.9	38.9	30.2	3.3	0.3	T	0.3	4.3	9.4	23.4	19.3	177.0
[in.]	7.8	11.0	15.3	11.9	1.3	0.1	T	0.1	1.7	3.7	9.2	7.6	69.7
Ft. Lupton													
cm	21.8	18.5	12.2	6.4	0.8	0	0	0	0	0.3	5.3	8.6	73.9
[in.]	8.6	7.3	4.8	2.5	0.3	0	0	0	0	0.1	2.1	3.4	29.1
Freeze													
No. days with temperature ≤ 0°C [32°F]													
Denver AP	29	26	25	13	1	+[a]	0	0	+	7	23	29	153
Ft. Lupton	30	27	28	15	2	+	0	0	1	13	27	30	173

Freeze threshold temperature		Mean number of days between date of last spring occurrence and first fall occurrence	
°C	[°F]	Denver AP	Ft. Lupton
0	32	160	148
-2.2	28	184	175
-4.4	24	198	196
-6.7	20	222	213
-8.9	16	230	226

[a] + = 0 > .5

Source: Decennial Census of United States Climate.

Table 7. TEMPERATURE, PRECIPITATION, SNOW AND FREEZE DATA, CHERRY CREEK DAM AND BYERS

Mean	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature													
Cherry Cr. Dam													
°C	-0.3	0.6	2.8	8.1	13.5	19.7	21.9	21.3	17.3	11.2	3.7	0.7	10.1
[°F]	31.5	33.1	37.1	46.6	56.3	67.4	71.5	70.3	63.2	52.2	38.6	33.3	50.1
Byers													
°C	-1.1	0.2	2.6	7.9	14.0	20.1	23.0	22.1	17.8	11.2	3.1	0.1	10.1
[°F]	30.1	32.4	36.6	46.2	57.2	68.2	73.4	71.8	64.1	52.1	37.6	32.1	50.2
Precipitation													
Cherry Cr. Dam													
mm	7.9	16.3	20.1	41.4	78.7	28.4	43.7	30.7	18.3	26.9	13.7	11.2	337.3
[in.]	0.31	0.64	0.79	1.63	3.10	1.12	1.72	1.21	0.72	1.06	0.54	0.44	13.28
Byers													
mm	11.2	13.0	22.1	34.0	65.8	30.7	58.2	40.9	20.8	21.8	14.0	8.9	341.4
[in.]	0.44	0.51	0.87	1.34	2.59	1.21	2.29	1.61	0.82	0.86	0.55	0.35	13.44
Snowfall													
Cherry Cr. Dam													
cm	22.1	21.6	28.7	22.9	3.0	0	0	0	1.5	16.0	15.7	22.9	154.4
[in.]	8.7	8.5	11.3	9.0	1.2	0	0	0	0.6	6.3	6.2	9.0	60.8
Byers													
cm	20.1	22.6	26.9	19.3	3.0	T	T	T	2.3	4.8	18.5	12.7	130.3
[in.]	7.9	8.9	10.6	7.6	1.2	T	T	T	0.9	1.9	7.3	5.0	51.3
Freeze													
No. days with temperature ≤ 0°C [32°F]													
Cherry Cr. Dam	29	27	28	17	3	+[a]	0	0	1	10	26	29	170
Byers	30	27	28	17	2	+	0	0	1	9	25	30	169

Freeze threshold temperature		Mean number of days between date of last spring occurrence and first fall occurrence	
°C	[°F]	Cherry Creek Dam	Byers
0	32	135	138
-2.2	28	155	168
-4.4	24	190	183
-6.7	20	211	204
-8.9	16	222	222

[a] + = 0 > .5

Source: Decennial Census of United States Climate; Climatological Data for the U.S.: Colorado.

than nine percent, as shown below (References 10,14).

County	Percent of total land area in county ≤ 5% slope	 ≤ 9% slope
Adams	63.7	75.5
Arapahoe	55.7	73.0

Elevation in the eastern plains section of Colorado ranges from 1,020 m [3,350 ft] at the lowest point in the state (where the Arkansas River crosses the border) to about 1,600 m [5,280 ft] around the Denver area. West of Denver, the plains give way abruptly to the foothills, with elevations of 2,100 m to 2,750 m [6,890 ft to 9,025 ft]. Typical elevations for sites within the study area are shown in Table 8. General elevations for the region are shown in Figure 5.

Table 8. TYPICAL ELEVATIONS FOR SITES WITHIN THE STUDY AREA

Study site	Nearby city or weather station	Elevation m	 [ft]
City park	Denver	1,609	[5,280]
Sod farm	Littleton	1,634	[5,362]
Sod farm	Brighton	1,518	[4,982]
Sod farm, irrigated farm, dryland farm	Fort Lupton	1,497	[4,914]
Irrigated farm	Platteville	1,469	[4,820]
Dryland farm	Watkins	1,685	[5,530]
Lowry Bombing Range	Cherry Creek Dam	1,721	[5,649]
Lowry Bombing Range	Byers	1,584	[5,200]

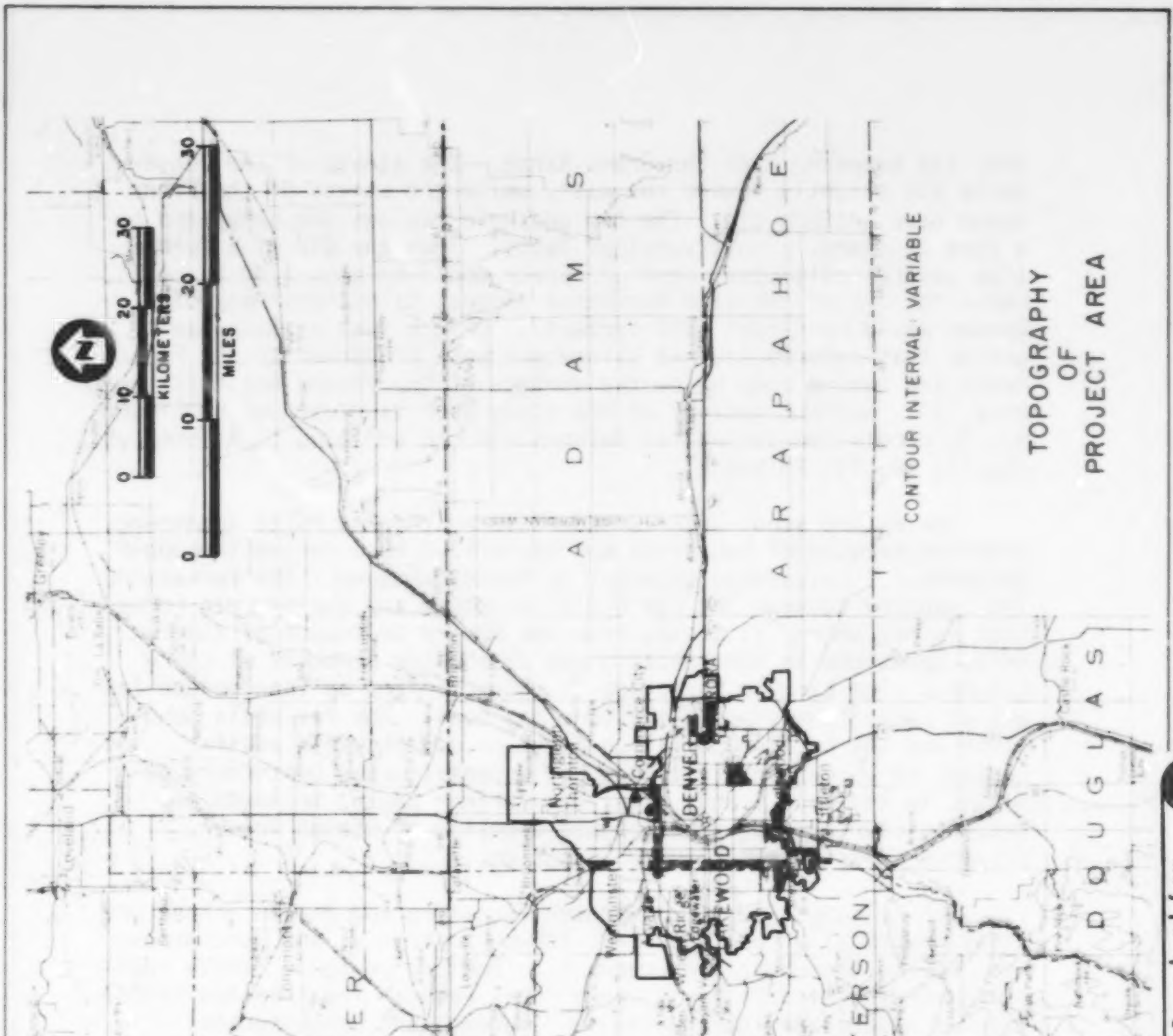
Many rivers and creeks flow out of the mountains and foothills, mostly in a south-to-north direction through the Denver region, in the Platte Drainage watershed. The South Platte River and Cherry Creek flow through the heart of Denver.

Separate discussion of the topography of the mine spoil site is presented under that heading in Appendix E.

GEOLOGY

The Metropolitan Denver area is located in the Denver Basin

FIGURE 5


KILOMETERS
0
10
20
30
MILES
0
10
20
30
N
BOULDER
GILPIN
CLEAR CREEK
JEFFERSON
DOUGLAS
ARAPAHOE
ADAMS
DENVER
CONTINENTAL DIVIDE
CONTOUR INTERVAL VARIABLE

TOPOGRAPHY OF PROJECT AREA

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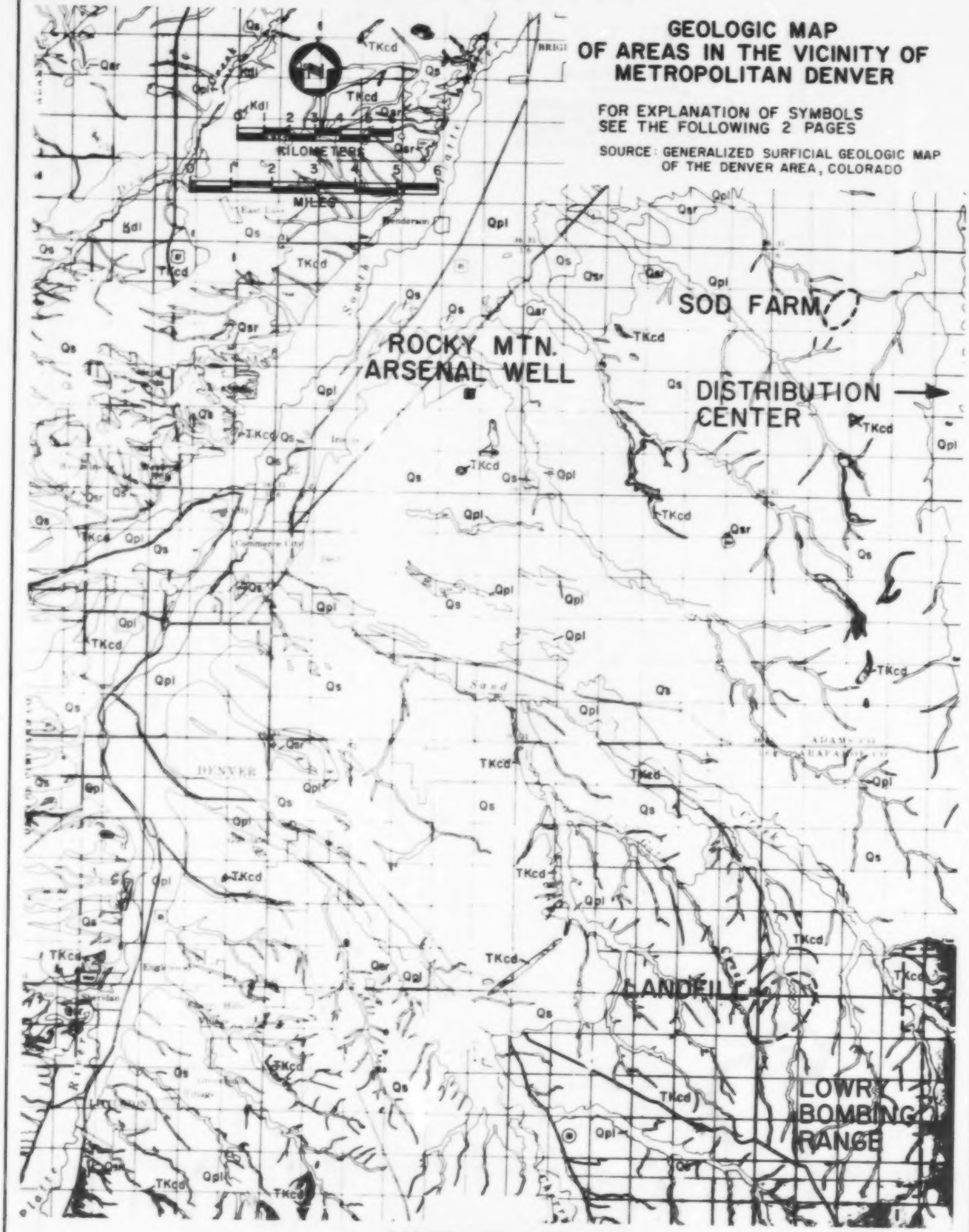
near its boundary with the Front Range. The strata of the Denver Basin dip slightly toward the east, while the strata of the Front Range have a steep dip. The two geologic regions are separated by a zone of sharp, almost vertical folds. Thus the dip of a formation several kilometers west of Denver would be high (>90 percent), while the dip of the same formation several kilometers east of Denver would be slight (<10 percent). Strata such as Cambrian gneiss that outcrop several kilometers west of Denver in the Front Range are buried deep below the surface of the Denver Basin (Reference 15). Surface geology of the study area is presented on Figure 6. More detailed geological information can be found in References 16, 17, 18, 19, 20 and 21.

The entire study area is underlain by the Fox Hills Sandstone, a marine deposit of sandstone and shale laid down during the Upper Cretaceous. Calcareous material is found throughout the formation. The boundary between the Fox Hills Sandstone and the Laramie Formation is not sharp; it grades from the marine sediments of the Fox Hills Sandstone to the brackish and freshwater deposits of the Laramie. The Laramie Formation is characterized by interbedded layers of shale, sandstone, limestone and coal. The Fox Hills Sandstone and the Laramie Formation serve as a high-yield aquifer. The Laramie is unconformably covered by unconsolidated Quaternary deposits in the Weld County area, and farther south, in Adams and Arapahoe counties, by intertongued deposits of Dawson Arkose, Arapahoe Sandstone and Denver Formation.

The Arapahoe Formation, Denver Formation and Dawson Arkose are stratigraphically contiguous, as shown on Table 9, and were deposited during the Upper Cretaceous and Tertiary periods. These sediments were derived from the young Front Range. The Arapahoe Formation is made up of interbedded sand, gravel and conglomerate. Plant and animal fossils are found throughout the Arapahoe and Denver formations.

The high groundwater yield of the Arapahoe formation can probably be attributed to the fact that the formation is only poorly to moderately cemented. The Denver Formation is a conglomeration of soft shale and siltstone interbedded with consolidated lenses of sand and conglomerate. In the lower part of the formation, tuffaceous and andesitic materials, which indicate volcanic activity, are found. The Dawson Arkose (sandstone with greater than 25 percent feldspar) is intertongued with the Denver, Arapahoe and Laramie formations. Arkosic grit, and, gravel, conglomerate and micaceous sandstone interbedded with shale characterize the Dawson Formation. Rhyolitic flows, tuffs and volcanic bombs are found in the upper part of the formation. As with the Arapahoe and Denver formations, the degree of cementation differs widely throughout the Dawson.

FIGURE 6



GEOLOGIC MAP OF AREAS IN THE VICINITY OF METROPOLITAN DENVER

FOR EXPLANATION OF SYMBOLS
SEE THE FOLLOWING 2 PAGES

SOURCE: GENERALIZED SURFICIAL GEOLOGIC MAP
OF THE DENVER AREA, COLORADO

ROCKY MTN. ARSENAL WELL
SOD FARM
DISTRIBUTION CENTER
LANDFILL
LOWRY BOMBING RANGE
KILOMETERS
0 1 2 3 4 5 6
MILES
DENVER
South Platte
Sand
Qs
Qpl
Qsr
TKcd
Kdl

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FIGURE 6 (cont.)

E X P L A N A T I O N

Holocene

Qs

Loess, eolian sand, colluvium undifferentiated

Wind-deposited silt, sand; sand and cobbles on foothill slopes. Silt and sand deposits 0-40 feet thick, sand and cobbles as much as 10 feet thick. Saturated sand and gravel may yield 1 to 5 gpm to wells

Pleistocene and Holocene

Qpl

Post-Piney Creek alluvium, Piney Creek Alluvium, pre-Piney Creek alluvium, Broadway and Louviers Alluviums

Sand, gravel, silt, and clay. Deposits range from 0-60 feet thick. Saturated sand and gravel yield as much as 2,000 gpm to wells. Chemical quality of water generally good

Pleistocene

Qsr

Slocum, Verdos, and Rocky Flats Alluviums

Reddish-brown silty clay, silt, sand, pebble lenses, and loess. Course gravel and sand and volcanic ash underlie high terrace remnants. Unit may exceed 50 feet in thickness locally. Yields 1 to 5 gpm to wells where materials are saturated. Gravel and sand near Barr Lake yield as much as 200 gpm to wells. Water generally of poor quality, contains excessive concentrations of fluoride

QUATERNARY

Paleocene and Oligocene

TKcd

Castle Rock Conglomerate, upper part of Dawson Formation, and upper part of Denver Formation

Gray, brown, tan, and greenish-gray shale, clay, and siltstone, and numerous lenticular beds of light-colored conglomerate and sandstone. Andesitic mudflow breccias common in vicinity of Table Mountains and Green Mountain. Beds of sandy limestone, lignite, coal, and carbonaceous shale are common. Unit ranges in thickness from 200 to 1,400 feet. Yields less than 25 gpm to wells in most of the area, but as much as 150 gpm in southeast part. Locally water contains high concentrations of dissolved solids, iron, radioactive constituents, and hydrogen sulfide gas

TERTIARY

Upper Cretaceous

Kdl

Lower part of Dawson Formation, Arapahoe Formation, and lower part of Denver Formation

White to yellow arkosic sandstone and conglomerate interbedded with gray, green, and red shale and claystone. Contains alluvial and mudflow andesitic detritus. Conglomerate beds thicken in upper part, and are thicker and more numerous toward southeast part of the basin. Unit ranges from 400 to 1,400 feet thick. Yields to wells average 100 gpm and are as much as 400 gpm. Water generally of good quality

Kl

Upper part of Laramie Formation

Blue-gray silty shale, thin silty sandstone, limestone, and coal; coal thickest in lower part. Yields 1 to 2 gpm of poor quality water to wells. Water contains hydrogen sulfide, iron, and methane

CRETACEOUS

Paleocene(?)

Tv

Volcanic rocks

Lava flows on Table Mountains, vent source near Ralston Creek, and ash flow tuffs near Castle Rock. Ash flow tuffs underlie Castle Rock Conglomerate. Not known to be saturated

TERTIARY

Geological map of areas in the vicinity of Metropolitan Denver (cont'd)

FIGURE 6 (cont.)

CRETACEOUS

Upper Cretaceous

Klf

Lower part of Laramie Formation and Fox Hills Sandstone

Medium-grained sandstone (60-80 feet), overlying and grading into finer grained thin-bedded sandstone interbedded with siltstone and shale (30-100 feet). Fine grained quartzose sandstone, siltstone, shale (80-120 feet). Wells penetrating entire unit generally yield 100 gpm and a few yield as much as 400 gpm. At places water may contain objectionable amounts of methane, hydrogen sulfide, iron, and fluoride

Lower Cretaceous

Kpb

Pierre Shale, Niobrara Formation, and Benton Shale

Gray, blue, and black shale, sandy shale, and thin limestone; some silty sandstone, bentonite seams, chalky marl, and limestone. Units may total 8,000 feet in Denver Basin. Fractured zones in shale may yield 1 to 2 gpm of poor quality water to wells

Kd

Dakota Group

Upper 100 feet gray-white fine- to medium-grained sandstone, thin-bedded to massive. Middle 150 feet dark-gray silty carbonaceous shale, contains refractory clay. Lower 60 feet gray coarse sandstone, locally conglomeratic, crossbedded. Sandstone yields 5 to 30 gpm to wells near outcrop. Water contains excessive iron locally

PENNSYLVANIAN THROUGH JURASSIC

JPr

Sedimentary rocks undifferentiated

Includes Upper Jurassic Morrison (300 feet) and Ralston Creek (120 feet) Formations; Triassic(?) and Permian Lykins Formation (400 feet); Permian Lyons Sandstone (200 feet); and Lower Permian and Upper and Middle Pennsylvanian Fountain Formation (1,200 feet). Lyons Sandstone, shown by stipple, generally yields 5 to 10 gpm, and as much as 80 gpm to wells near outcrop areas. Fountain Formation sandy conglomerate may yield 1 to 5 gpm to wells. Water may contain excessive iron and fluoride

PRECAMBRIAN

p€r

Igneous and metamorphic rocks undifferentiated

Granite, gneiss, schist, quartzite, pegmatite, quartz veins, intrusive igneous rocks. Yield 1 to 5 gpm of generally good quality water to wells that tap fractures or weathered zones

Contact

Fault

Geological map of areas in the vicinity of Metropolitan Denver (cont'd)

Table 9. STRATIGRAPHIC UNITS AND THEIR WATER-BEARING PROPERTIES IN THE VICINITY OF DENVER

System	Series	Subdivision		Thickness m[a]	Physical character	Water-bearing properties		Water yield, liters per second[b]	
Quaternary	Recent and Pleistocene	Dune sand		0 - 15	Fine to medium sand and minor amounts of clay and silt.	Serves mainly as medium for recharge from precipitation. Locally yields small quantities of water to domestic and stock wells.		0.1 - 0.3	
		Slope wash		0 - 9	Poorly sorted clay, silt, sand and gravel; grades into valley-fill deposits.	Yields small to moderate quantities of water to domestic and stock wells and to a few irrigation wells.		125	
		Valley-fill deposits		0 - 40	Interbedded clay, silt, sand and gravel that contains some cobbles and boulders and beds of altered volcanic ash. Underlies the flood plain and terraces on the South Platte River valley and underlie floor of Beebe Draw and Box Elder Creek Valley. Include some slope wash along the edges of Beebe Draw and Box Elder Valley.	The most important aquifer in the report area and the source of groundwater for nearly all the large-capacity wells. Yield moderate to large quantities of water to many domestic, stock, irrigation, public-supply and industrial wells.		125	
	Pleistocene	Upland deposits		0 - 5	Deposits of sand, gravel, conglomerate and volcanic ash that mantle the bedrock in the upland areas. Include colluvium, residuum and remnants of pediment and terrace deposits.	Topographically high and well drained. Not a known source of water for wells. Serve as medium for recharge from precipitation.		0.3 - 13	
Tertiary	Paleocene	Dawson arkose	Denver formation	0 - 60	Varicolored clay, soft shale and siltstone containing much carbonaceous material, interbedded with lenticular poorly sorted generally moderately indurated yellowish-brown sandstone and conglomerate. Locally contains andesitic material and beds of weathered volcanic ash and bentonitic clay.	Yields small quantities of water to domestic and stock wells in the southern part of the report area.	The Dawson arkose, stratigraphically equivalent to part of the Denver and Arapahoe formations, yields small to moderate quantities of water to domestic, stock, public-supply and industrial wells in the southeastern part of the report area.	1 - 9	1 - 9
Cretaceous	Upper Cretaceous		Arapahoe formation	0 - 185	Upper part (120 m): Soft predominantly blue or gray sandy to clayey shale and clay and a few lenticular beds of sandstone. Lower part (60 m): White to yellow sand, gravel and conglomerate, variously indurated and including minor amounts of shale and clay.	Yields small to moderate quantities of water to domestic, stock, public-supply and industrial wells in the southern part of the report area.		6 - 25	
		Laramie formation		0 - 185	Upper part (120 m): Chiefly olive-gray silty shale and siltstone and lenticular silty sandstone; contains numerous carbonaceous clay beds and lignitic seams. Lower part (60 m): At top, a sequence of thin beds of blue-gray silty shale, sandstone and lignitic material. At bottom several relatively thin beds of sandstone, fairly thick beds of subbituminous coal, and several other thinner sandstone units that locally coalesce with the thick basal sandstone.	Some of the sandstone units in the upper part yield small to moderate quantities of water to domestic, stock and industrial wells throughout the report area. The basal sandstones in the lower part yield small to moderate quantities of water to domestic, stock, public-supply and industrial wells throughout the area.		upper: 0.1 lower: 6 - 25	
		Fox Hills sandstone		0 - 75	Uniformly bedded buff to pale-yellow friable medium-grained sandstone interbedded with gray to black silty shale and silty sandstone. About 15-18 m of massive sandstone at top.	Yields small to moderate quantities of water to domestic, stock, public-supply and industrial wells throughout the report area.		6 - 25	

[a] 1 meter = 3.281 feet

[b] 1 liter per second = 15.85 gallons per minute

Source: Ground Water Resources of the South Platte River Basin in Western Adams and Southwest Weld Counties, Colorado

The Dawson Arkose and Denver formations, unlike the Arapahoe, have poor groundwater yield and serve as an aquitard. The upper parts of these formations outcrop in southeastern Arapahoe County.

Most of the surface of the study area is covered by unconsolidated Quaternary deposits which range in thickness from 0 to 20 m [0 to 66 ft].

Early in the Quaternary, before the Wisconsin glaciation, debris from the Front Range formed large deltas in the Denver Basin. The deltas included layers of silt, sand and gravel as well as some volcanic ash. The pre-Wisconsin Quaternary deposits are designated as Qsi on the geologic map presented on Figure 6. The water yield of these deosits is small and generally of poor quality.

During the Wisconsin glaciation, the Denver Basin, particularly the western portion near the city of Denver, served as an outwash area for the glaciers in the mountains to the west. The torrential flow of the outwash streams eroded the underlying deltas and deposited as much as 20 m [66 ft] of sand, gravel, silt and clay over them. Thus outcrops of the Qsr formation represent topographic highs which were not destroyed by the outwash streams. The alluvium from the glacier forms an aquifer with good water quality and yield as high as 125 lps [2,000 gpm]. The Wisconsin alluvium is depicted as Qpl on the geologic map. Strong winds capable of carrying heavy bedloads also characterize outwash areas. The winds shift the unconsolidated alluvium. These eolian deposits, depicted as Qs on the geologic map, cover more of the surface than does any other deposit in the study area. They range in thickness to about three meters [10 ft] and have a small yield (about 0.3 lps [5 gpm]).

The proposed sludge reuse sites, except for the irrigated farms in Weld County, are plotted on the geologic map. In general, water-bearing formations used intensively as a groundwater source are less suitable for sludge disposal. Many other factors are important, however; the geologic character of an area cannot be the only criterion for site selection.

Earthquakes

During the history of Denver, only one earthquake of damaging proportions has been reported near Denver. In the mid-1960's, however, several mild earthquakes occurred. These earthquakes centered around the Rocky Mountain Arsenal well, where millions of gallons of contaminated water were injected into the highly faulted pre-Cambrian bedrock (Reference 19). In the future, it is unlikely that major earthquakes will occur in the Denver area. It will probably not be necessary to incorporate earthquake lateral force considerations into design features for the sludge disposal systems.

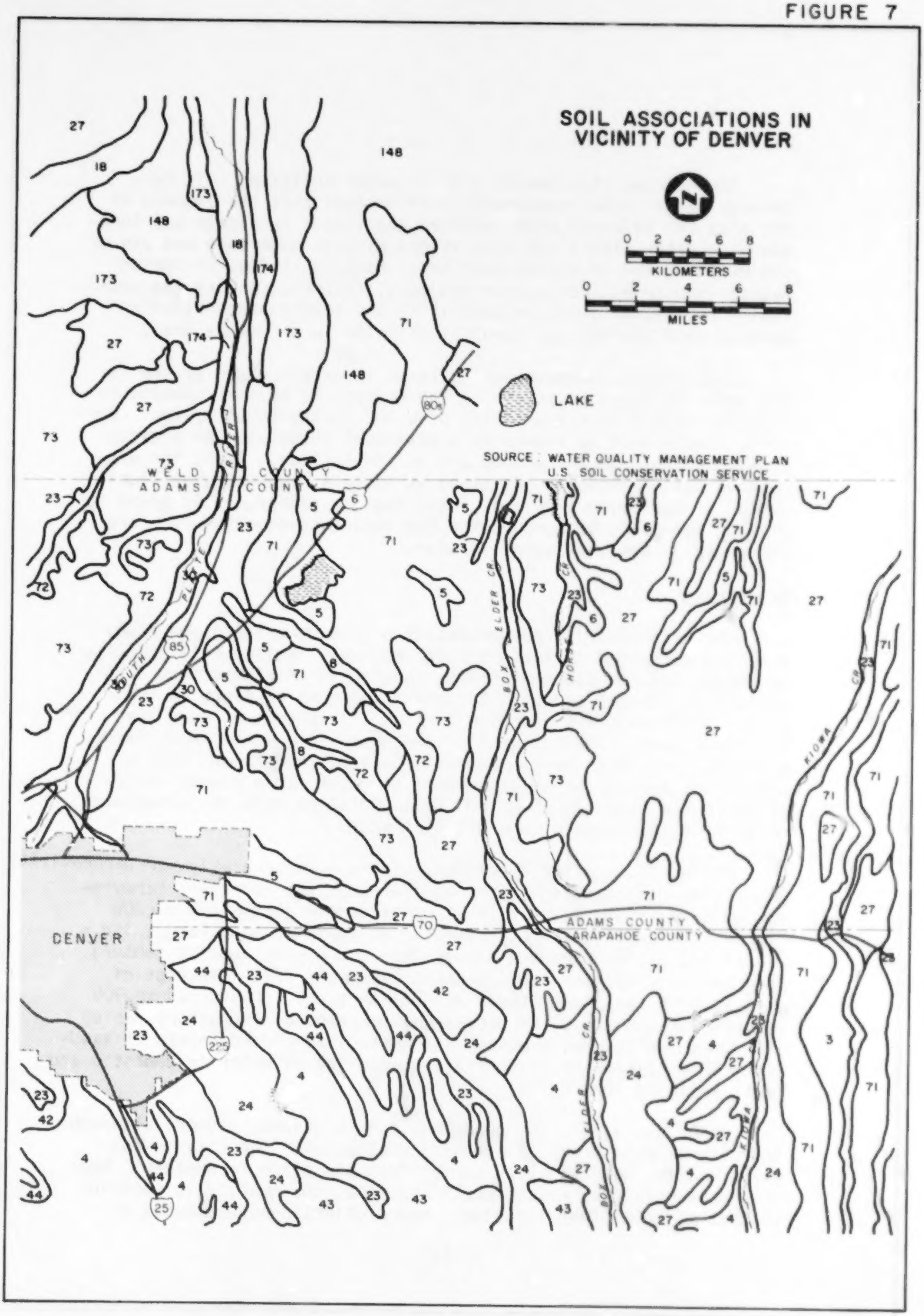
SOILS

Soils in the study area have been surveyed by the U.S. Soil Conservation Service (SCS) in recent years. Final reports on detailed soil surveys have been published for Adams County (Reference 10) and Arapahoe County (Reference 14). As for Weld County, a detailed survey has been completed, but no published report is available. Official soil series descriptions and interpretations for the Weld County soils which may be subjected to sludge application were obtained from the SCS field office in Greeley (Reference 22).

Soils in most of the potential areas of sludge application are for the most part calcareous. They fall within about 20 distinct associations with characteristics typical of their geographic setting. The topography, drainage, texture and parent materials of these soils are presented in Appendix B and are shown graphically on Figure 7. Specific characteristics of soils in each typical site under investigation are presented separately under the discussion of the environmental setting of the particular site in Appendix E. The published soil surveys are indispensable as a tool for planning sludge use in agriculture on a regional basis. However, for application on a specific field, this information should be augmented with additional field investigations by soil scientists and/or agronomists.

An important soil property which should be carefully considered in sludge application is the micro-community inhabiting the soil. Microbial populations living in the soil include viruses, bacteria, actinomycetes, fungi, algae and protozoa. Soil aeration, acidity, temperature, moisture content, organic matter, inorganic nutrient supply and other parameters determine the relative populations of the various microbial groups. Some of the important functions of soil microorganisms, insofar as sludge application is concerned, are (1) uptake of nutrient elements and their conversion to organic matter, (2) production of growth factors stimulating other organisms, (3) breakdown of complex organic molecules to simpler, more readily usable forms, (4) production of antibiotics which inhibit some organisms, (5) symbiotic relationships between certain organisms, (6) predation and parasitism between organisms, (7) nitrogen fixation from the atmosphere under certain conditions and (8) production of enzymes which promote many different biochemical reactions.

FIGURE 7



SOIL ASSOCIATIONS IN VICINITY OF DENVER

SOURCE: WATER QUALITY MANAGEMENT PLAN
U.S. SOIL CONSERVATION SERVICE

0 2 4 6 8
KILOMETERS
0 2 4 6 8
MILES
LAKE
WELD COUNTY
ADAMS COUNTY
ARAPAHOE COUNTY
DENVER
SOUTH PLATTE RIVER
BOX ELDER CR
HORSE CR
KIOWA CR
6
80N
85
70
225
25
27
18
173
148
174
71
73
23
72
30
5
8
44
24
4
42
43
3

WATER

The Metropolitan Denver area is water-deficient. It is through large-scale transmountain diversions that the demands of the area are balanced with imported supplies. Intricate and long-standing water rights and allocations dictate ownership and use of the existing and developed supplies. Municipalities, irrigated farms, industries, recreation projects, fisheries and stream aesthetic requirements impose cumulative and sometimes conflicting demands upon quality and quantity of water in the study area.

Even though sludge-handling is an important phase of the total water management picture in the region, it neither demands nor supplies significant quantities of water to the total system. However, sludge must be viewed as a potential threat to the quality of waters, both in the ground and on the surface. Thus, the discussion that follows is not aimed at being a comprehensive elucidation of the water supplies of the region; rather, it is meant to provide the basic background for the impact statements which are presented in the succeeding sections.

Groundwater

The water-bearing properties of strata underlying the study area are presented in Table 9 under Geology. Valley fill deposits of Recent and Pleistocene series, ranging in thickness from 0 to 40 m [0 to 125 ft] comprise the most important aquifers in the area. These aquifers underlie various thicknesses of dune sand and slope wash. The valley fill deposits yield moderate to large quantities of water to the domestic, stock, irrigation, public supply and industrial wells. Depth to water table ranges from a meter [a few feet] to 30 m [100 ft]. Detailed data on groundwater occurrence and movement are not available.

Below this aquifer formation, strata with generally low permeability (aquitards) separate the upper aquifer from the important Laramie-Fox Hills aquifer, which lies at considerable depths (90 m [300 ft] at Platteville; 520 m [1,700 ft] at Lowry Bombing Range; 400 m [1,300 ft] at the proposed sludge drying and distribution center) from the land surface. Wells penetrating the full thickness of this aquifer can yield from 6 to 60 liters per second [100 to 900 gallons per minute]. The Denver-Dawson-Arapahoe formations, which lie above the Fox Hills aquifer, do have interbedded layers of sandstone which yield low to moderate quantities of water to domestic and stock wells in the region

Water quality in the upper aquifer is generally good, although scarcity of data preclude adequate evaluation. The Laramie-Fox Hills aquifer water quality varies from one place to another. Near its recharge sites, to the south and east, the quality is superior to that at some other locations, where objectionable amounts of methane, hydrogen sulfide, iron and fluorides are encountered.

Surface Water

Even though the study area is interlaced with many of the tributaries of the South Platte River, most of the creeks in the eastern part of the study area are dry during most parts of the year. Some streambeds are wet only on rare occasions: once every several years. Streams draining the western parts of the Metropolitan Denver area flow during most of the year and include St. Vrain Creek, Boulder Creek, Coal Creek, Big Dry Creek, Clear Creek, Sand Creek, Cherry Creek, Bear Creek, Plum Creek and many smaller creeks. Many diversion structures across streams on the western slopes of the Continental Divide have been constructed to transfer water through the mountains to the eastern slopes and to discharge the water in the above-mentioned streams. These water diversions, reservoirs built on the creeks themselves, groundwater withdrawals, irrigation diversions and their return flows have drastically changed natural flow patterns in these streams. A discussion of the quantities and quality of water in the streams, as well as a model of stream water quality in the Denver Basin, are presented in the recently published Water Quality Management Plan (Reference 9).

During the period 1966 through 1970, annual stream flow into the Metropolitan Denver area totaled 450 million cubic meters [185,600 cfsd], 95 percent of which was diverted from the streams. Fully 38 percent of the streamflow into the Denver Area in that period was wastewater treatment plant effluents from upstream areas, and over half of the water leaving the metropolitan area was generated within the area (Reference 9).

The lakes in and around the metropolitan area are of special significance. Most of the lakes were used for irrigation before the area became heavily urbanized. Most are now used for recreation and as centers of real estate development. There are some 50 lakes with surface areas greater than 10 hectares [25 acres], with a total combined area of 3,686 hectares [9,108 acres] and a total shoreline of 185 km [115 miles]. The three largest lakes are:

Lake	Surface area hectares	[acres]
Barr	708	[1,750]
Standley	492	[1,216]
Chatfield	465	[1,149]

There are another 113 lakes of 2 to 10 hectare [5 to 25 acre] surface area, with a total area of 526 hectares [1,300 acres] and a shoreline of 110 km [68 miles] (Reference 23).

Water quality in the lakes has deteriorated progressively over the past decades with chemical and biological pollutants emanating from the increasingly heavy use and development of the surrounding area. A recent investigation of the present quality of waters in these lakes, including parameters such as salinity, pH, transparency and coliform bacteria, is reported by the U.S. Geological Survey in graphic format (Reference 23).

Site B-2 straddles a low ridge separating the upper drainage areas of Lost and Horse Creeks. Both are intermittent prairie streams. Horse Creek drains into Horse Creek Reservoir, which is used primarily for irrigation. Lost Creek flows into Prospect Valley, an intensively irrigated area in Weld County.

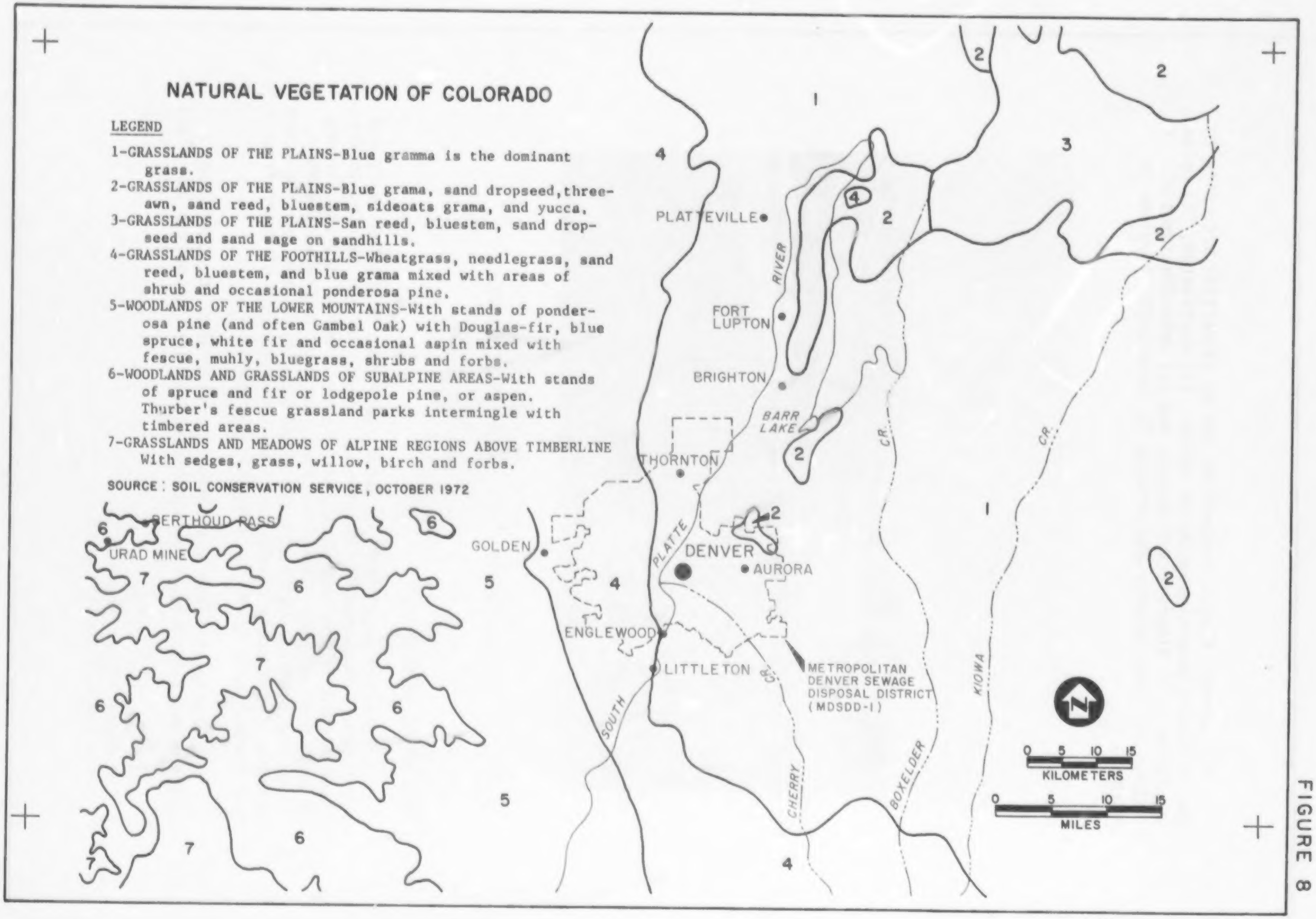
BIOLOGY

The Metropolitan Denver region is part of the high plains area that extends from the Great Plains to the foothills of the Rocky Mountains. The elevation of the study area ranges from 1,400 m to 1,800 m [4,600 ft to 6,000 ft], placing it within the Upper Sonoran life zone (Reference 24). This zone begins at the Transition zone of the foothills of the Rocky Mountains and extends beyond the eastern border of Colorado. The growth and distribution of vegetation is largely dependent upon climate, relief, substrate, fire and the occurrence of human activities such as grazing and agriculture. With an average annual precipitation rate of only 30 to 40 cm [12 to 16 in.], water availability is the chief limiting factor leading to the low growth of grasses and forbs on the plains.

Prior to settlement, the plains supported a mixed prairie which was made up primarily of perennial bunchgrasses. Short grasses such as blue grama and buffalo grass dominated on drier sites, and taller grasses (western wheatgrass and little bluestem) occurred on sites with higher moisture, such as along eastern stream courses and toward the mountains to the west. Prior to settlement, a very complex mosaic of steppe communities existed in the Denver area in response to the numerous soils (Reference 9). Under natural conditions, the three major plant communities probably were (1) upland prairie or short-grass plains, (2) meadow and (3) cottonwood-willow. The plains did not support tree growth except along the watercourses, which were fringed with cottonwoods and willows. Dense thickets of wild plum and chokecherry, with scattered clumps of hackberry and box elder, occurred sometimes in gulches and arroyos (Reference 24). The original distribution of natural vegetation in the Denver region (Reference 25) is shown in Figure 8.

Human activities, mainly in the form of cultivation and livestock grazing, have altered the natural vegetation considerably. Sixty-five percent of Adams County is currently under cultivation, and 35 percent of Arapahoe County is similarly utilized. The remaining uncultivated lands are generally used for pasture and range or urban and residential purposes (References 10,14).

FIGURE 8



NATURAL VEGETATION OF COLORADO

LEGEND

1-GRASSLANDS OF THE PLAINS-Blue gramma is the dominant grass.
2-GRASSLANDS OF THE PLAINS-Blue grama, sand dropseed, three-awn, sand reed, bluestem, sideoats grama, and yucca.
3-GRASSLANDS OF THE PLAINS-San reed, bluestem, sand dropseed and sand sage on sandhills.
4-GRASSLANDS OF THE FOOTHILLS-Wheatgrass, needlegrass, sand reed, bluestem, and blue grama mixed with areas of shrub and occasional ponderosa pine.
5-WOODLANDS OF THE LOWER MOUNTAINS-With stands of ponderosa pine (and often Gambel Oak) with Douglas-fir, blue spruce, white fir and occasional aspin mixed with fescue, muhly, bluegrass, shrubs and forbs.
6-WOODLANDS AND GRASSLANDS OF SUBALPINE AREAS-With stands of spruce and fir or lodgepole pine, or aspen. Thurber's fescue grassland parks intermingle with timbered areas.
7-GRASSLANDS AND MEADOWS OF ALPINE REGIONS ABOVE TIMBERLINE With sedges, grass, willow, birch and forbs.

SOURCE: SOIL CONSERVATION SERVICE, OCTOBER 1972

BERTHOUD PASS
URAD MINE
GOLDEN
PLATTEVILLE
FORT LUPTON
BRIGHTON
BARR LAKE
THORNTON
DENVER
AURORA
ENGLEWOOD
LITTLETON
METROPOLITAN DENVER SEWAGE DISPOSAL DISTRICT (MDSDD-1)
SOUTH
PLATTE
RIVER
CHERRY
CR.
BOXELDER
CR.
KIOWA
CR.
N
0 5 10 15
KILOMETERS
0 5 10 15
MILES
1
2
3
4
5
6
7

The present biotic communities can be calssified according to the following general vegetation units: (1) Cultivated, (2) Uplands Vegetation, (3) Riparian and Aquatic and (4) Urban/Residential. A listing of common plants and animals in these units is given in Appendix C.

TYPICAL UPLAND VEGETATION UNIT WITH COTTONWOOD TREES INDICATING SEASONAL RIPARIAN ZONE

Cultivated Lands Unit

Cultivated vegetation includes sod farms, irrigated farms and dry farms. Thousands of hectares of the plains are devoted to irrigated farming along the South Platte River, and to dryland farming on adjoining uplands. In some areas, such as in Arapahoe County, irrigated farmland has decreased significantly in the past 30 years because of community development and the diversion of water from the South Platte River for domestic purposes.

Agricultural lands are typically cultivated as monoculture units. The allocation of large parcels of land to only a few plant species leads to a simplified environment with low animal diversity. Animal populations are generally characterized by numerous small burrowing rodents, seed-eating birds and a few wide-ranging predator species. Although a monoculture yields little variety in habitat, the crops provide an important food source for wildlife. This is particularly significant in migratory bird wintering areas near Riparian-Aquatic habitats. The stubble, fence rows and unharvested remains are often vital to wildlife for sustenance and cover during the winter months. Such a situation exists at Site B-2; a small area of relictual prairie on the southeast end offers additional habitat to wildlife.

Uplands Unit

Uplands vegetation includes pasture and range lands whose species composition varies with soil character and past use. Current Upland vegetation on uncultivated soils is typically a weedy grass type that has suffered from too heavy grazing. The two major short-grass species of the mixed prairie, blue grama and buffalograss, are hardy perennials that can withstand heavy grazing since they grow close to the ground and form a cover of bunchy sod. Both of these grasses increase when tall-grass associations are overgrazed. When overgrazing occurs on the short-grass units, the sod mats weaken and are invaded by annual grasses and annual and perennial weeds (Reference 26). Good examples of the tall-grass prairies and mixed-grass prairies are now becoming scarce in the Denver region (Reference 9).

Wildlife patterns have also changed in response to prairie succession and alterations in land use. Formerly abundant animals such as the prairie dog, American buffalo and pronghorn antelope have become limited in distribution because of human intervention and changes in the short-grass prairie habitat. The black-footed ferret, which had a historic range dependent upon that of the prairie dog, is considered an endangered species (Reference 27). The greater and the lesser prairie chicken are examples of species which are endangered by the diminishing size of the mixed prairie habitat. The Uplands vegetation area is now primarily inhabited by jackrabbits, rodents and many reptiles which are tolerant to change and can coexist with human activities.

Riparian and Aquatic Unit

Riparian and Aquatic units occur along major watercourses, such as the South Platte River and Cherry Creek. Associated with most watercourses are wide, nearly flat floodplains. Many of the creeks in the study area seldom flow for more than two weeks, generally in March and April and during heavy storms in the summer. Most of the suitable terrace soils along streams have been cultivated, and other Riparian zone sites, which have not been utilized for gravel mining or occupied by industrial sites, have been grazed for 100 or more years. In bottom lands where there is no current grazing, there is a greater variability in vegetative cover (Reference 9).

Colorado's semiarid Front Range Urban Corridor has many lakes of high value. In the past, they were used to store water for irrigation and domestic uses, with occasional use for recreational activities. As a result of rapid suburban development, their importance at present is as recreational areas and centers of real estate development. The major lakes of the Denver region are Cherry Creek Lake, Chatfield Lake, Marston Lake, Standley Lake and Barr Lake. The network of smaller lakes, ponds and reservoirs also plays an important role in the natural ecosystem.

Riparian and Aquatic units include some of the most important wildlife habitat in the area. The Platte River Valley and its tributaries produce one-third of Colorado's annual water fowl crop and provide winter habitat for tens of thousands of migrant birds. The trees of the floodplain supply nesting and roosting areas for large numbers of birds of many kinds, including small numbers of bald eagles. In the metropolitan area, most marshlands have been eliminated, although many floodplain oxbow lakes, ponds and marshes persist in the more rural areas. Marshes provide a valuable wildlife habitat, serving as home for amphibians and aquatic mammals, and as nesting and feeding grounds for waterfowl. The dense vegetation provides excellent winter storm cover for pheasants, rabbits and many other kinds of wildlife (Reference 9).

The larger lakes of the Denver region are stocked with gamefish such as brown trout and rainbow trout. All lakes generally contain several species of roughfish, which provide important food supply for wildlife as well as maintaining the aquatic ecosystem. Lakes and ponds that are less disturbed by human activities comprise the necessary aquatic habitat for migrant waterfowl.

Urban/Residential Unit

The original site of Denver was a virgin prairie traversed by two tree-lined streamcourses. With urban growth and development, a large variety of non-native shrubs and trees have been introduced into the Denver area. A vast City park system interlaces the city, providing a wealth of greenery, open space and artificial lakes and ponds. Denver has more than 100 parks covering more than 1,100 ha [2,800 acres], as shown on Figure 3.

The present vegetation is a cross-section of many plant types from midwestern and eastern United States. Parks and residential areas are lined with shade and fruit trees, ornamental shrubs and flower gardens. Many large areas are landscaped with grasses and other ground covers for recreational use. This wealth of foliage has attracted several midwestern birds, such as the red-eyed vireo and bronzed grackle, unknown within the area before 1910 (Reference 28). Thus, in the past century, the urbanization of Denver has resulted in the creation of woodland, shrub and aquatic habitats in formerly barren areas.

A summary of the major biotic units, with their characteristic plant and animal species, is shown in Figure 9.

Rare and Endangered Species

The Federal Register for rare or endangered plant species was reviewed for the State of Colorado (Reference 34). No plant species were considered to be threatened in the Denver Region.

The Nongame and Endangered Species Conservation Act (Reference 35) for the State of Colorado is consistent with Title 50, Part 17 of the U.S. Conservation of Endangered Species Act. The Colorado Division of Wildlife further protects several wildlife species not covered by the Federal Conservation Act. The Wildlife Division has recognized the stress on wildlife caused by a growing population and changing land use, and endeavors to protect wildlife habitat as well as endangered wildlife species. Animals protected by State and Federal regulations (Reference 34) that may occur within the study area include the black-footed ferret, peregrine falcon, white pelican, and river otter.

Black-Footed Ferret--

The black-footed ferret (*Mustela nigripe*) occurs within shortgrass prairies. Its historic range coincides closely with that of its prey species, the prairie dog. The population has been drastically reduced and its range decreased due to changing land uses and programs to control or eliminate prairie dogs. Scattered reports of the black-footed ferret indicate nearly statewide distribution, with tendencies toward the eastern grasslands. The lands within the study area are largely cultivated or grazed and probably represent a marginal habitat for the black-footed ferret.

Peregrine Falcon--

Colorado has two recognized subspecies of the peregrine falcon: a winter nesting resident, the American peregrine (*Falco peregrinus anatum*), and the arctic peregrine (*Falco p. tundrius*), a migratory visitor during the spring and fall (Reference 36). The resident subspecies is of greater concern within the Rocky Mountain area. Human activities such as road-building, forest- and sagebrush-clearing, game-hunting and outdoor recreation have deteriorated the quality of

FIGURE 9

Unit	Location and examples	Characteristic vegetation	Characteristic birds	Characteristic animals
Cultivated Lands	Flat or rolling farmlands; east and north of Denver. Major portions of Weld and Adams counties.	Alfalfa, corn, sugar beet, vegetables, wheat, oats, barley, rye, forage sorghum.	Brewer's blackbird, western vesper sparrow, ring-necked pheasant, western meadowlark, lark bunting.	Meadow vole, pocket gopher, ground squirrel, harvest mouse, western jumping mouse, weasel, bullsnake, garter snake.
	Rural dwellings; farm buildings.	Sunflower, prickly lettuce, Russian thistle, tansy mustard, dandelion, garden escapes.	Barn swallow, Say's phoebe, housefinch.	House mouse, raccoon, feral cat, spadefoot toad, garter snake.
	Steep dirt banks; along ditches and seasonal streams.		Bank swallow, kingfisher.	Fence lizard.
Uplands Vegetation	Arid plains region; typically found in eastern Adams and Arapahoe counties.	Blue grama grass, buffalo grass, western wheatgrass, little bluestem, Junegrass, needle-and-thread, red three-awn, locoweed, sunflower, aster, fanweed, prickly pear, plantain, yucca.	Burrowing owl, desert horned lark, mountain plover, turkey vulture, red-tailed hawk.	Jackrabbit, prairie vole, pocket mouse, Ord kangaroo rat, coyote, pronghorn antelope, prairie rattlesnake, bullsnake, central plains milksnake, sagebrush lizard, horned lizard.
	Bluffs and cliffs		Cliff swallow, prairie falcon, ferruginous roughleg hawk.	

Summary of biotic community characteristics, Metropolitan Denver area

FIGURE 9 (cont.)

Unit	Location and examples	Characteristic vegetation	Characteristic birds	Characteristic animals
Riparian and Aquatic	Cottonwoods; along rivers and streams such as South Platte River and Cherry Creek.	Plains cottonwood, box elder, willow, narrow leaf cottonwood.	Red-headed woodpecker, Rocky Mountain screech owl, Swainson's hawk, crow, Bullock's oriole, kingbird, western mockingbird, white-rumped shrike.	Raccoon, fox squirrel, shrew, weasel, bat, barred tiger salamander, yellow-bellied racer, garter snake.
	Shrubbery; along streams and creeks and intermittently between stretches of cottonwood.	Chokecherry, wild plum, buffaloberry, hawthorn, rabbitbrush. willow.	Black-headed grosbeak, catbird, brown thrasher, yellow warbler, song sparrow.	Striped skunk, raccoon, eastern woodrat, deer mouse, yellow-bellied racer, garter snake.
	Lakes and ponds; storage reservoirs such as Barr Lake and ponds throughout farming region and urban areas.	Willow, rushes, cattail, sedge, salt grass and aquatic plants.	Grebe, gull, tern, goose, green heron, mallard, pintail, shoveler and other ducks, shorebirds.	Snapping turtle, box turtle, boreal chorus frog, carp, brown trout, chub, minnow, shiner, catfish.
	Marsh areas and swamps; along the floodplain of South Platte River.	Salt grass, bulrush and other rushes, sedge.	Rail, coot, heron, bittern, duck, red-winged blackbird, yellowthroat.	Muskrat, coyote, bullfrog, leopard frog, boreal chorus frog, garter snake, northern watersnake.
Urban/Residential	Greater Denver Metropolitan area; includes residential environs, City parks and other recreational facilities.	Ornamental shrubs, flowers, lawn-type grasses, soft maple, elm, weeping willow, Carolina & Lombardy poplar, ash sycamore, Norway pine, Russian olive, and several varieties of fruit trees.	Robin, starling, mockingbird, house sparrow, black-capped chickadee, chipping sparrow, rock dove, red-eyed vireo, bronzed grackle.	House mouse, Norway rat, pocket gopher, feral cat.

Source: References 28, 29, 30, 31, 32 and 33.

Summary of biotic community characteristics, Metropolitan Denver area (contined) the environment for this species. The peregrine falcon requires high cliffs for nesting sites and a food supply of small birds. Accurate information about breeding pairs has been difficult to obtain. However, the plains area may still have some value as a feeding range for this species (Reference 36).

White Pelican--

The white pelican (*Pelicanus erythrorhynchos*) is common in portions of the United States and is not considered endangered on a national basis. Within Colorado, it is presently considered endangered as a nesting summer resident. White pelicans may be found at several reservoirs along the South Platte River drainage; however, they nest and rear young only at Riverside Reservoir, outside of the study area.

River Otter--

The river otter (*Lutra canadensis*) formerly ranged over many of the rivers and lakes of North America. Due to hunting and human encroachment, otters have been eliminated or their numbers reduced over much of their range. However, the river otter is not considered endangered on a national basis. The otter has probably always been rare in Colorado (Reference 36). Scattered sightings have been reported in the South Platte River drainage in Weld County, and it is unlikely that a breeding population is present. Because this species is usually limited to wilderness areas, it is unlikely that it could ever exist in any numbers in the study area. Most of the streams and lakes are influenced by adjacent homes, industry or other incompatible human developments.

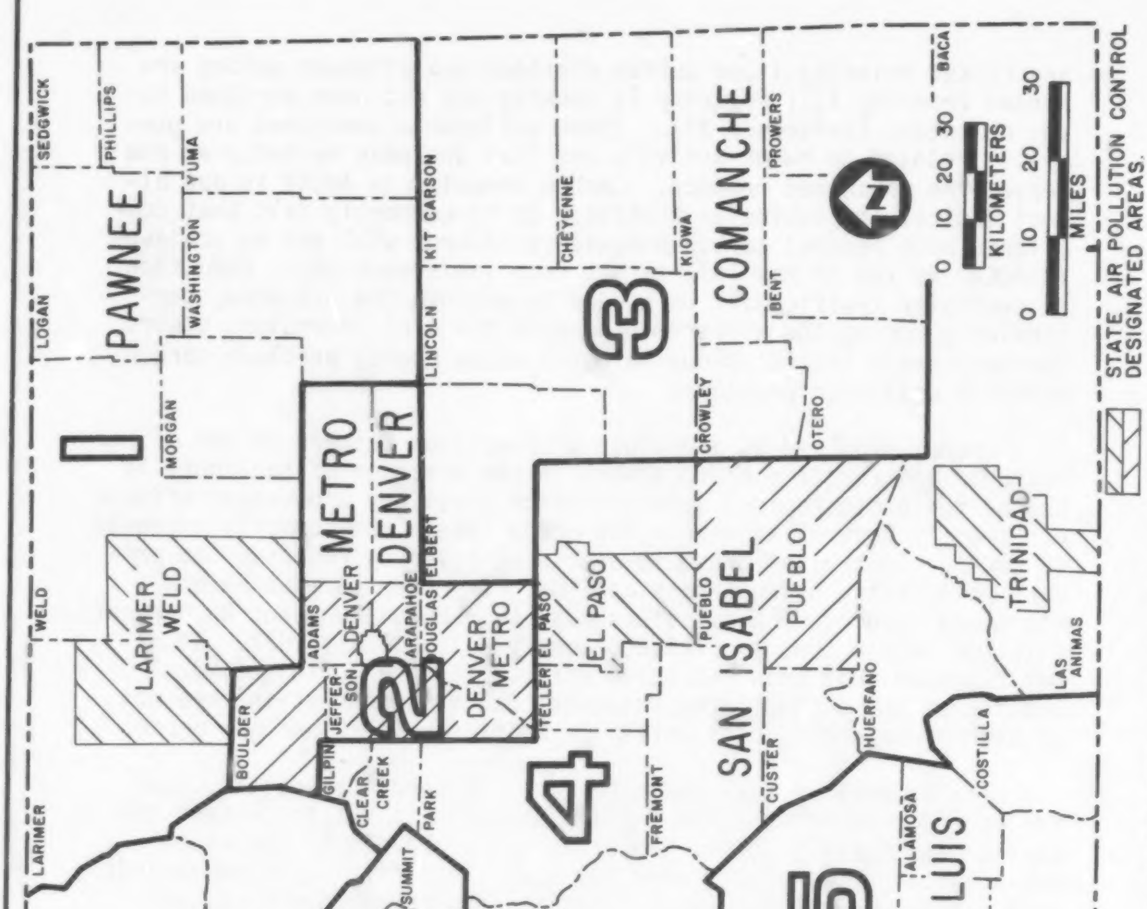
AIR QUALITY

The project study area is located within Air Quality Control Region 2 (AQCR2)--Metropolitan Denver (see Figure 10). Air pollution control priorities for this region have been determined by the Colorado Air Pollution Control Division and the U.S. Environmental Protection Agency on the basis of the following five considerations:

1. existing air quality data
2. population status and trends
3. degree and type of industrialization (emission inventory)
4. amount of vehicular traffic
5. topographic and meteorologic factors

On the basis of these criteria, pollutants are given priority rankings of I, II or III, with Priority I as the most severe. Particulates, carbon monoxide and reactive hydrocarbons and oxidants

FIGURE 10


1
PAWNEE
2
METRO DENVER
DENVER METRO
3
COMANCHE
4
SAN ISABEL
5
SAN LUIS
6
FOUR CORNERS
7
GRAND MESA
8
YAMPA
LARIMER WELD
EL PASO
PUEBLO
TRINIDAD
SEDGWICK
PHILLIPS
LOGAN
WASHINGTON
YUMA
MORGAN
WELD
KIT CARSON
LINCOLN
CHEYENNE
KIOWA
PROWERS
BACA
BENT
CROWLEY
OTERO
ELBERT
ADAMS
DENVER
ARAPAHOE
DOUGLAS
JEFFERSON
BOULDER
GILPIN
CLEAR CREEK
PARK
TELLER
EL PASO
PUEBLO
FREMONT
CUSTER
HUERFANO
LAS ANIMAS
COSTILLA
ALAMOSA
CONEJOS
RIO GRANDE
MINERAL
SAGUACHE
LARIMER
JACKSON
GRAND
SUMMIT
LAKE
CHAFFEE
ROUTT
EAGLE
PITKIN
GUNNISON
HINSDALE
ARCHULETA
SAN JUAN
LA PLATA
OURAY
DELTA
MOFFAT
RIO BLANCO
GARFIELD
MESA
MONTROSE
SAN MIGUEL
DOLORES
MONTEZUMA
0 10 20 30
KILOMETERS
0 10 20 30
MILES
N
STATE AIR POLLUTION CONTROL DESIGNATED AREAS.

SOURCE: COLORADO DEPARTMENT OF HEALTH, AIR POLLUTION CONTROL COMMISSION.

COLORADO AIR QUALITY CONTROL REGIONS

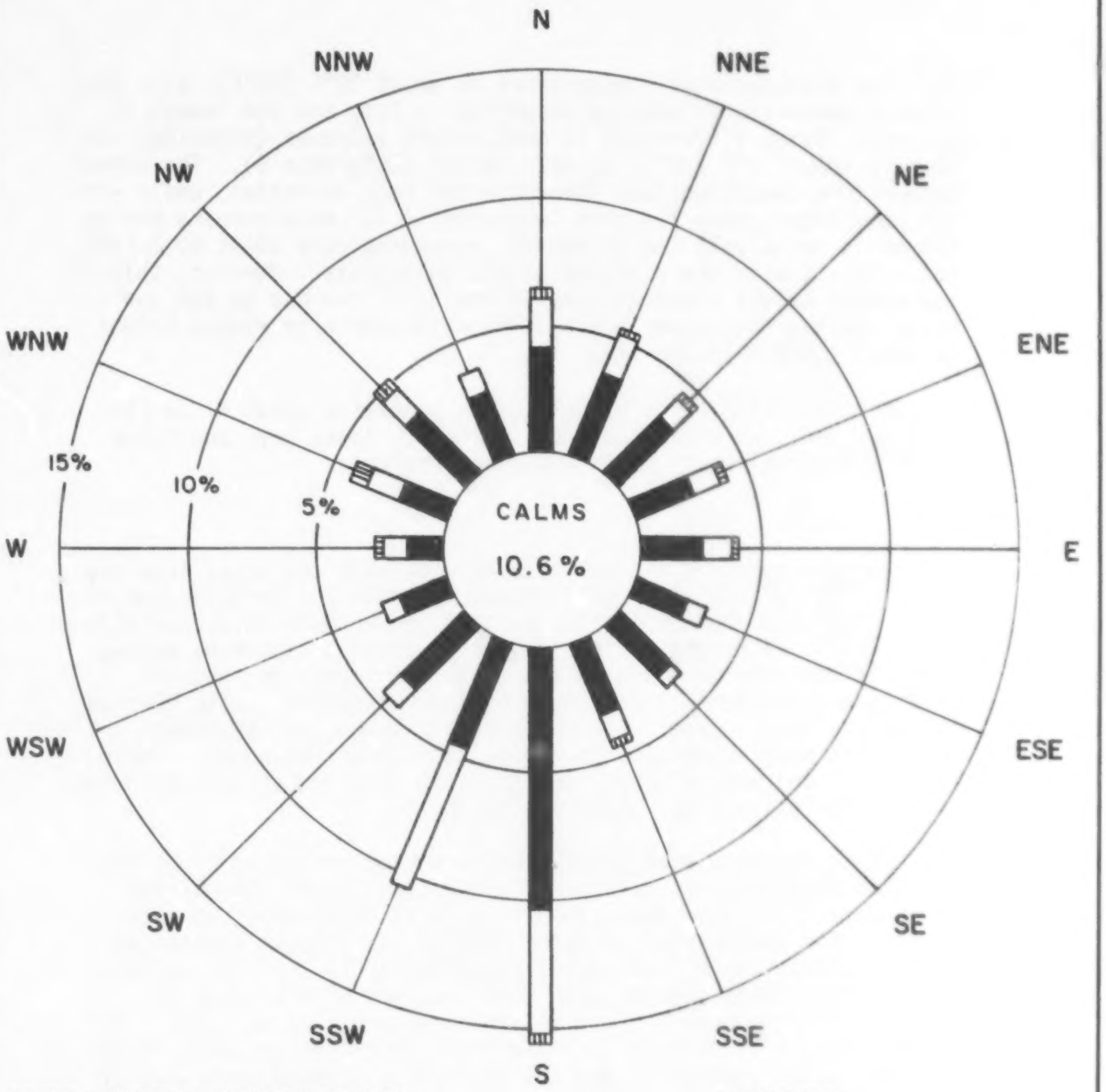
are ranked Priority I and sulfur dioxides and nitrogen oxides are ranked Priority III; Priority II ranking has not been assigned to any pollutant (Reference 37). These pollutants mentioned are generally related to human activity and thus decrease markedly as one leaves the urbanized regions. Carbon monoxide in AQCR2 is due almost entirely to vehicular traffic. It is currently felt that compliance with Federal carbon monoxide standards will not be achieved in AQCR2 by the 31 May 1977 target date (Reference 37). Reduction in vehicular traffic will be needed to achieve the standard, particularly during the winter months when frequent inversions occur. The very small traffic flows in rural Adams County preclude carbon monoxide pollution problems.

Ozone, produced as a product of reactions between oxides of nitrogen and reactive hydrocarbons in the presence of sunlight, is one of the photochemical oxidants which cause the unpleasant effects of "smog." Federal standards for ozone levels are commonly exceeded in AQCR2. Control of these levels is achieved by reducing the primary pollutants, hydrocarbons and NO_x. In order to meet Federal standards, hydrocarbon emissions must be reduced by about 80 percent (110,000 metric tons/yr [120,000 tons/yr]) by 31 May 1977. It is not expected that this reduction will be attained. In the rural setting of the project area, however, ozone concentrations are not as high as in urban areas, although sporadic violations may occur.

The Federal primary and secondary standards for particulates are exceeded in AQCR2. The primary standard is set to protect the public health at 75 $\mu g/m^3$, geometric mean. Levels in the urban Denver area are generally over 100 $\mu g/m^3$, diminishing to two-thirds this level in outlying areas. Contaminants previously discussed are monitored at only six stations in the Metropolitan Denver area. The particulate concentrations are sampled more widely (22 stations). The monitoring station nearest the project is in Brighton, about 16 km [10 miles] northwest of the sludge drying sites. In 1974, a year of average meteorological conditions, the annual arithmetic mean particulate level was 103 $\mu g/m^3$. The State standard is 70 $\mu g/m^3$. While rural areas may experience high particulate levels due to agricultural operations, these levels are generally lower than those of urban areas. For this reason, particulate levels around the project site are not presently considered significant.

Wind transport of pollutants into or away from the project area can be surmised from wind speed and direction, as described on Figure 11. The data used in this figure, from Stapleton Airport on the northeast edge of Denver, are representative of wind patterns in the study area. The average wind speed and direction is 15 km [9.5 miles] per hour from the south. Infrequent strong, destructive winds generally come from the northwest.

FIGURE 11



SOURCE: BASED ON 10 YEARS OF DATA (DECENNIAL CENSUS), 1951-1960, BY JOHN BENCI, DEPT OF ATMOSPHERIC SCIENCE, COLORADO STATE UNIVERSITY (REFERENCE 38).

LEGEND

SYMBOL	WIND SPEED
■	1.8 - 5.4 mps (4 – 12 mph)
□	5.4–11.0 mps (13–24 mph)
▥	> 11.0 mps (> 24 mph)

ANNUAL FREQUENCIES OF WINDS OF VARIOUS VELOCITIES AT STAPLETON AIRPORT, DENVER COLORADO

The average annual temperature is about 10°C [50°F], with the highest temperatures usually occurring in July and the lowest in January. Daily differences in temperature extremes (high-low) are usually about 17°C [30°F] in most months (Reference 8). The summer temperature conditions are favorable for smog formation, while winter conditions cause frequent inversions. The mean morning mixing height is relatively low in Denver, averaging only about 60 m [200 ft]. This limits the dilution of air pollutants. However, this low mixing height rises quickly in the afternoon due to the sun's heat. During the summer months, the afternoon mean mixing height is about 1,000 m [3,300 ft].

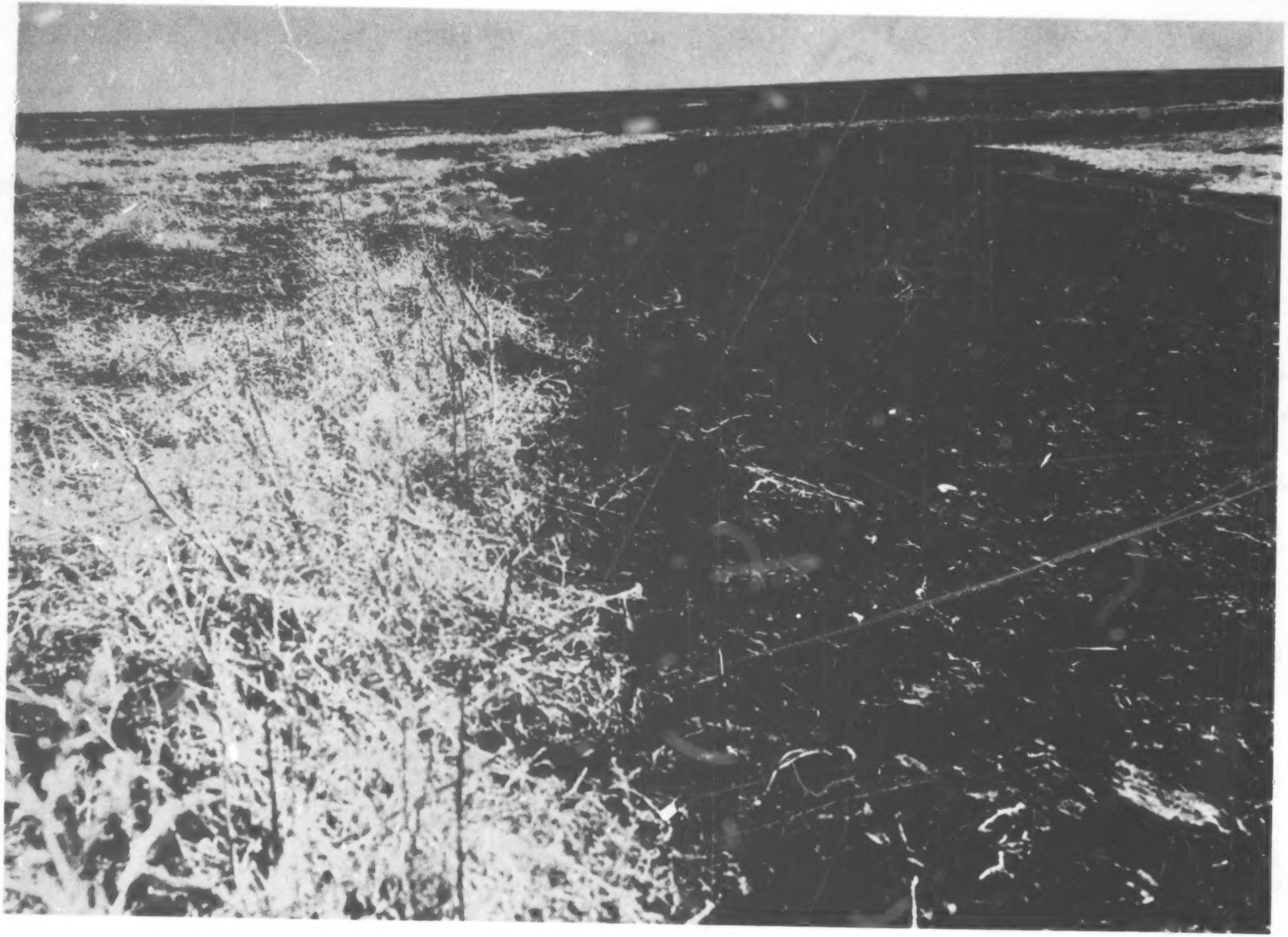
Precipitation is relatively mild, averaging about 41 cm [16 in.] per year, as discussed under Climate. These dry conditions cause additional particulate emission problems.

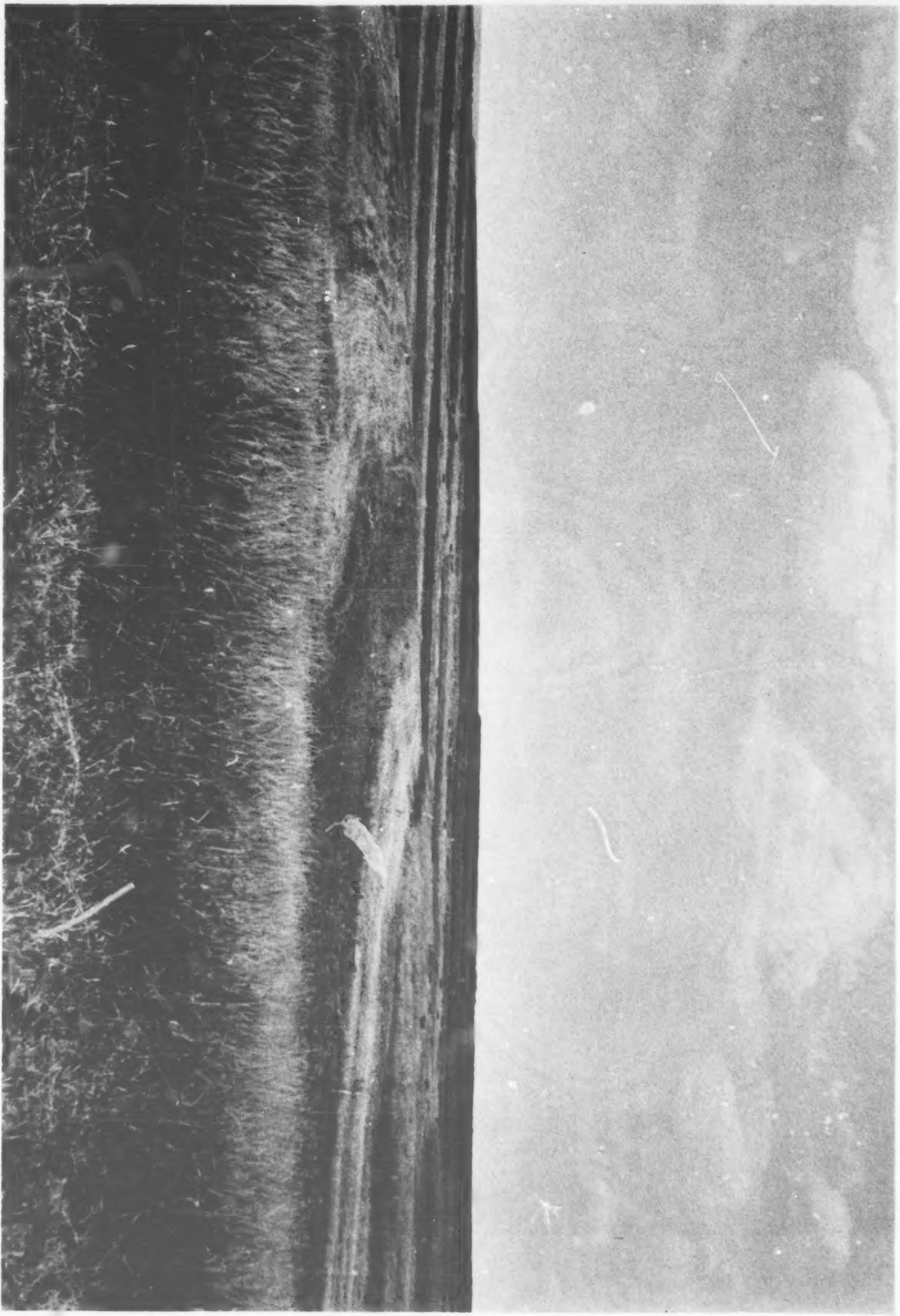
Odor

Background odors generally associated with the study area are those normally associated with urban, suburban and farming communities. The petroleum refineries east of Denver emit characteristic odors which are especially noticeable at distant locations during calm periods when mixing with the upper air layers is minimal. Other odorous materials are those commonly associated with farming operations in the area. For example, a chicken farm may heat-pressurize chicken manure, producing very offensive odors. These fertilizer and manure odors are generally accepted as part of normal farm operations and are therefore tolerated.

Odors are regulated by Odor Emission Regulation No. 2 of the Colorado Department of Health, Air Pollution Control Commission (Reference 37). This regulation sets forth three types of odor limits. For residential or commercial areas, odorous substances must be undetectable from beyond the property line of the emission source after being diluted with seven volumes of odor-free air. A scentometer allows this dilution and measurement to be taken. For other areas, a dilution of 15 volumes of odor-free air must render the odor undetectable. A special regulation exempts agricultural and manufacturing processes, provided the best practicable methods have been employed to control odors. For all odor sources, however, there is an upper limit which must not be exceeded: they must not be detectable after having been diluted with 127 volumes of odor-free air.

Because of the potential for emission of odorous air contaminants from the drying and distribution center, an emission permit from the Air Pollution Control Division of the Colorado Department of Health will be required.





ARCHAEOLOGY AND HISTORY

Transient and sedentary Indian tribes once associated with eastern Colorado and the general Great Plains complex include the Ute, Cheyenne, Arapaho, Comanche, Kiowa, Pawnee and Plains Apache (Reference 42). Because of the locational association with the proposed project, an archaeological survey was undertaken and was completed in August 1974 (Reference 8). The primary survey area was the proposed drying basin site, where major excavation activities would take place.

During its investigation, the archaeological team found no surficial evidence of existing archaeological sites on the proposed drying basin site; a single, isolated *mano*, probably of Ute origin, was discovered immediately to the northeast of the site. The team determined that, since the proposed site has been under long-term cultivation, any artifacts lying on or near the surface would have been scattered during plowing and seeding activiites. During the course of the survey, the team did discover evidence of a nearby archaeological site, approximately 8 km [5 miles] to the northeast of the proposed drying basin site.

While land beneath the Metro Denver Plant may contain a concealed archaeological site, the land has undergone development, and any surficial evidence would have been scattered or destroyed.

As indicated on Figure 1, the proposed pipeline route lies along and within various roadway rights-of-way (See map in Volume II, Issue I-2). Consequently, any evidence of associated archaeological sites would have been obliterated through adjacent road building activities.

Representative off-site distribution areas have also been disturbed in the last century by human activities such as cultivation, mining and park-building. Surface archaeological remnants would not be present on these areas.

In terms of historical importance, no known historical site has been officially designated on or near project sites which lie in Adams County (Reference 43). Since the proposed project operation will not disturb any existing historical sites on or near sludge recycling areas, no historical survey was conducted for this project.

LAND USE

Areas in the proximity of the proposed project are presently used for a variety of urban and rural land use purposes. Those areas which are entirely urban in function include land in the immediate vicinity of the Metro Denver Central Plant and various parks in the Denver area which will become project distribution sites. Areas which are rural include the drying basin site, the Urad Mine and the sod, irrigated and dryland farms. Other project-related areas consist of the proposed pipeline route and the Lowry Bombing Range site, which also contains the landfill site.

The Metro Denver Plant facility which will house the anaerobic digesters is located within the Denver urban core area. Use of the lands immediately surrounding this facility is industrial and includes a rendering plant, a refinery and a variety of factories.

The site proposed for the drying basins is rural in character. While some of the site and the land adjacent to it is used for pasturing, the majority is under dryland cultivation, with wheat as the principal crop. Buildings within one kilometer of this site include a farmhouse and two structures related to agriculture, all of which are located 0.4 km [1/4 mile] east of the site. Subdivisions in the vicinity are located on five four-hectare [10-acre] lots to the northwest of the site, but none is closer than six km [four miles] (Reference 44). The area is zoned for agriculture and large subdivision lots. County land use plans would continue agriculturally related uses but also propose an airport facility for this area (References 45,46). As proposed, the Adams County General Aviation facility will be in excellent conformity with the drying basin site since the facility will be flat, low and sparsely populated (Reference 47).

The Urad Mine, under consideration for sludge application, lies in a rural area of Clear Creek County approximately 13 km [8 miles] west of the city of Empire. While the mine is not presently used, evidence of mining operations remains, including deforested land and large volumes of tailings and other mining wastes deposited near the vacant mines. Amax, Inc. plans eventually to revitalize the area by application of its "Comprehensive Plan for Land Reclamation and Stabilization at the Urad Mine" (Reference 48). In time, the area will be restored through reforestation and revegetation activities (Reference 48).

The sod farm chosen as representative for sludge recycling lies close to the drying basin site and, like that site, is part of a rural, agricultural area where wheat is the primary crop. Because of its proximity to Box Elder Creek, turf and river bottom grasses are also grown here. The only structures on the property are a few farm buildings.

The representative irrigated farm also lies in an area which is devoted to farming activities. It is located approximately 2.4 km [1.5 mile] east of Platteville, which is a small, rural community.

Buildings lying on the property include a farmhouse, barn and storage shed.

Dryland farms to be used for sludge application are coterminous with the representative sod and irrigated farm areas and therefore have common environmental characteristics.

The pipeline proposed for transport of the processed sludge from the Central Plant to outlying drying basins will traverse both urban and rural land. Initially the line will pass through the industrialized area surrounding the Central Plant. It will then cross into Commerce City, a suburb of Denver, and skirt the Rocky Mountain Arsenal. From that point it will run beneath the Irondale Road right-of-way, through land which is rural in character, until it reaches the drying basin site in Adams County.

Because the area surrounding the Lowry Bobming Range is sparsely developed and lightly populated, it may be characterized as rural. No change from its present use as a sludge deposition and landfill site is proposed at present. However, potentially detrimental levels of heavy metals may have accumulated in the soils (Reference 45), and this situation may limit its future land use potential.

LAND TENURE

The Metro Denver treatment plant facilities are situated on publicly owned lands. Various roadway right-of-way areas which will accommodate the proposed pipeline are also publicly owned, as are the project-related parks in the Denver area. The Lowry Bombing Range, which contains the Lowry Landfill site, is partly U.S. Air Force property, partly private and partly state-owned. Privately owned lands include the proposed 800-hectare [2,000-acre] drying basin site, the Urad Mine area and the representative sod, irrigated and dryland farms.

POPULATION

Regional Population

The service area where the sludge originates and the areas to receive the dried sludge are located within the jurisdiction of the Denver Regional Council of Governments (DRCOG). Recent DRCOG population trends, disaggregated according to county, are given in Table 10.

In common with major metropolitan areas throughout the country, there has been a recent shift in population from the central city to the suburbs. During the year 1974-75, while Denver County's population remained essentially static, two of the three counties

Table 10. POPULATION BY COUNTY, 1970-1975

County	1970	1971	1972	1973	1974	1975
Adams	183,000	191,600	202,800	213,200	225,600	232,100
Arapahoe	161,000	166,800	179,000	196,000	211,300	224,800
Boulder	130,000	136,700	145,200	156,300	164,200	171,500
Clear Creek	4,600	5,500	5,700	5,700	5,700	5,900
Denver	514,000	518,600	523,700	528,000	529,600	529,700
Douglas	8,000	9,700	10,900	13,100	15,800	18,000
Gilpin	1,200	1,500	1,600	1,900	1,900	2,000
Jefferson	231,000	245,700	264,500	292,300	310,800	322,800
Region	1,232,800	1,276,100	1,333,400	1,406,500	1,464,900	1,506,800

Note: All estimates as of January 1 of each year.

Source: "Population Change in the Seventies."

which contain the suburban communities around Denver grew at a rate faster than that for regional annual population growth, which was 2.97 percent: Arapahoe County, 6.4 percent, and Jefferson County, 3.9 percent; the third, Adams County, grew at a rate of 2.9 percent, nearly equal to the regional rate (Reference 49).

Regional growth reached a peak rate of 5.5 percent per year in 1972-73 and has since declined to a rate close to the 1960-1970 average of 2.6 percent. This decline in growth rate is attributed to declining fertility rates, restrictions on new gas and water connections which began in 1972 and a general economic slowdown, which has reduced the rate of immigration into the region and has brought new residential construction almost to a standstill (Reference 49).

Metropolitan Denver Sewage Disposal District No. 1

The population within Metropolitan Denver Sewage Disposal District No. 1 (Metro Denver) in 1975 was 1,081,000 (Reference 50). The District serves most of the population of Adams, Arapaho, Jefferson and Denver counties.

Adams County

Adams County, a rapidly growing section of the Denver Metropolitan area, had the highest growth rate among the DRCOG counties from 1940 to 1950. In the 1950's it almost tripled its population. This growth has leveled somewhat over the past two decades, as shown in Table 11.

Table 11. POPULATION GROWTH RATES, ADAMS COUNTY

(percent per year)

Growth period	Growth rate Annual	Growth rate Average
1940-1960		6.8
1960-1970		4.4
1970-71	4.7	
1971-72	5.8	
1972-73	5.1	
1973-74	5.8	
1974-75	2.9	
1970-1975		4.9

Source: Reference 49.

Almost two-thirds of the population of Adams County is concentrated in the cities of Aurora, Northglenn, Commerce City, Thornton and Westminster. About 95 percent of the population is in urban areas. The sewage from 78 percent of the population of Adams County is generated and treated within the Metro Denver district. Adams County accounts for 17 percent of the population in the Metro Denver service area.

Population Projections

Projections of population for the counties of concern are given in Table 12.

DRCOG population estimates were adjusted by Metro Denver staff for use in their Long Range Planning Study. These figures give a total District projection for the year 2000 which is 16 percent higher than that projected by DRCOG for the same area for that year (Reference 9). Table 13 shows a range of eight projections for the five-county Denver region for the year 2000. On the basis of the 16 percent difference mentioned, it would appear that Metro Denver's projections fall somewhere near the middle of the range of projections made by various agencies.

The projected sludge load increases used to estimate the 1985 levels are given in Table 14 along with Metro Denver and DRCOG population growth assumptions for a similar time period.

TRANSPORTATION AND CIRCULATION

Roadway, railroad and air travel are the primary modes of transportation used in the region of the proposed project. While roadways serve most areas, railroad travel is concentrated on lines passing through Denver and airplane travel facilities are interspersed throughout the region.

Roadways of a variety of types serve the region. Minor streets and arterials are found in urbanized areas, particularly those surrounding the City and County of Denver, along with state, interstate and federal highways (Reference 56). In rural and sparsely populated areas, roadways are limited to minor streets and arterials, which are variously classified, depending on surface composition characteristics and design width (Reference 57). In general, these roads are infrequently travelled, with average daily travel (ADT) ranging from 90 to 230; however, many are adequate in design to carry heavy, agriculturally related trucks and can accommodate an ADT as high as 6,200 (Reference 59).

Railroads in the region are concentrated around Denver. These

Table 12. SELECTED POPULATION PROJECTIONS FOR COUNTIES IN VICINITY OF METRO DENVER

County	Population, 1975[a]	State of Colorado projections[b], 1995 low	State of Colorado projections[b], 1995 high	DRCOG projections[c] 1990	DRCOG projections[c] 2000
Denver	529,700	392,000	538,000	602,000	709,100
Adams	232,100	314,000	432,000	295,000	326,000
Arapahoe	224,800	322,000	443,000	345,000	413,000
Jefferson	322,800	483,000	664,000	515,000	658,000
Weld	114,000	138,000	160,000	(not in DRCOG)	

[a] Source: Reference 51 for Weld County, Reference 49 for all others.

[b] Source: Reference 51.

[c] Source: Reference 52, Denver Regional Council of Governments.

Table 13. POPULATION FORECASTS FOR THE FIVE-COUNTY DENVER REGION IN THE YEAR 2000

Agency	Population estimate
U.S. Department of Commerce, Office of Business and Economic Research Service (OBERS)	1,981,000
Colorado Land Use Commission	2,175,000
Denver Regional Council of Governments (DRCOG) (policy forecast)	2,350,000
Denver Research Institute (DRI)	2,675,000
Colorado Division of Planning (county total)	2,886,000
Colorado Division of Planning (city total)	2,892,000
Metropolitan Denver Water Study Committee	3,000,000
Colorado Division of Planning (adjusted city total)	3,399,000

Source: "Appraisal of the DRCOG Policy Population Forecast."

Table 14. POPULATION AND SLUDGE LOAD PROJECTIONS FOR METRO DENVER DISTRICT

Projections	Time period	Year			Average annual growth rate, %
		1970	1977	1985	
DRCOG population projection for Metro Denver district[a], persons	1970-1985	1,074,775		1,469,420	2.1
Metro Denver population projection[b], persons	1970-1985	1,080,032		1,683,400	3.0
Metro Denver sludge load projection[c], dry metric tons/day	1977-1985		68	97	4.8

[a] Source: Reference 9.

[b] Source: Reference 47.

[c] Source: Reference 55.

include the Union Pacific and Burlington-Northern Railroad lines. Although there is variation in routes, most of the lines pass through Denver (Reference 56). The line closest to the proposed sludge drying basin site lies 11 km [7 miles] to the south.

Airport facilities located within the region include Stapleton International Airport in Denver and a variety of noncommercial private facilities in Adams, Arapahoe, Weld and Denver counties (Reference 60). The proposed Adams County General Aviation Airport is located in the proximity of the area slated for the sludge drying basins.

RECREATION

The State of Colorado is divided into several recreational regions. Denver, Adams, Weld and Arapahoe counties are included in Metro Region No. 9, while Clear Creek County lies in the North-Central Colorado Region No. 7 (Reference 43). There are a number of officially designated recreational areas within these two regions. They include reservoirs, rivers and streams, natural lakes, cold springs, forests the parks (Reference 43). Recreational areas of several types are found near the proposed project. The proposed South Platte River recreational area is located approximately 1.6 km [one mile] east of the Metro Denver Plant; Barr Lake and Barr Lake Duck Club lie 18 km [11 miles] northeast of the proposed drying basin site. In the vicinity of sludge recycling sites are the Big Bend Picnic Grounds, about 1.6 km [one mile] northeast of the Urad mine; the Old Fort Vasquez site, about 1.6 km [one mile] southwest of the Platteville sod farm; and 120 developed neighborhood parks in Denver County (Reference 40).

INSTITUTIONAL AND GOVERNMENTAL AGENCY JURISDICTIONS

The jurisdictional issue of principal concern for the proposed project is the conflict between Adams County and Metro Denver over final approval of the drying and distribution center. Since the proposed site for this operation is within unincorporated County territory, and therefore under the jurisdiction of the Adams County Planning Commission, the County feels it should have the power to accept, modify or veto the operation. Very recent litigation has determined that Metro Denver needs a Certificate of Designation from the Adams County Board of Commissioners in order to proceed. The application for Certificate of Designation, including supporting documents (such as this Draft EIS), would be reviewed by the Colorado Department of Health, who would recommend approval or disapproval to the County Commissioners (Reference 61). If approval is not forthcoming, the District can attempt to exercise its power to condemn property required for its operations (Reference 62).

A recent amendment to Colorado State solid Waste legislation has removed the need for farmers using sludge for agricultural purposes to obtain a certificate of designation. Metro drying facilities will still be required to obtain such a certificate.

Most of the farmlands affected by the proposed project are within unincorporated County territory and are under the jurisdiction of the Adams County Planning Commission.

The Colorado Board of Land Commissioners is the Statewide planning body responsible for the management of State lands. The State of Colorado owns about 130 hectares [320 acres] of the recommended site (B-2).

The regional planning body with jurisdiction in the study area is the Denver Regional Council of Governments (DRCOG). This is a planning agency whose purpose is to coordinate plans of local and county governments and to ensure, through the A-95 review process, that federally funded projects are in harmony with these coordinated plans. DRCOG has studied the feasibility of coordinating a solid waste management program with Metro Denver's sludge management system, but found that coordination of programs is uneconomical at this time. As of March 1976, the Colorado legislature has let die proposed legislation which would have made regional solid waste management possible.

The U.S. Environmental Protection Agency is the Federal body charged with managing the Federal funds provided for construction of the proposed project. Another Federal agency with jurisdiction and interest in the proposed project is the U.S. Food and Drug Administration (FDA). The FDA generates and enforces regulations for the application of sludge on crops which enter the human food chain if they are to be used in interstate commerce. Jurisdiction over the immediate health concerns associated with the project is held by the Tri-County District Health Department. This Department oversees the present operations at Lowry Bombing Range and would also be responsible for checking the proposed operation in Adams County.

The City of Denver uses a small portion of the Lowry Bombing range for the disposal of its solid wastes. Metro Denver Sewage Disposal District uses on an interim basis another area of the range which is owned by the City and County of Denver. The City maintains jurisdiction over the area, and no long-term or written agreement is in effect between the two entities. The City has expressed its intent to eventually utilize the additional Lowry space, including the 240 ha [600 acres] of present Metro operation, for its own future sanitary landfill operations (see letter in Volume II and Reference 63).

SOCIO-ECONOMIC SETTING

Adams County Agricultural Economy

Agriculture has been the mainstay of the Adams County economy since homesteaders first arrived in the 1860's (Reference 45). Almost 95 percent of the area of the county is presently in agricultural use.

In 1973, Adams County ranked seventh among the 65 counties in the state in winter wheat production, tenth in barley, seventeenth in sugar beets, nineteenth in corn for grain, twentieth in sorghum for grain and eleventh in total crop production.

Truck farming activities in western Adams County are concentrated along the Platte River. The main irrigated crops are alfalfa, corn, barley, sugar beets, oats and rye. Greenhouses and turf farms are increasing, and this trend is expected to continue (Reference 45). Dryland farming is carried out primarily in the eastern part of the County (including the vicinity of the proposed drying and distribution center site). The main nonirrigated crops are winter wheat, forage sorghum and barley. The values of the various crops produced in Adams County are shown in Table 15.

Livestock population in Adams County is shown in Table 16.

Sources of Fertilizer

Nitrogen fertilizers are manufactured using nitrogen from the atmosphere and hydrogen from fossil sources (coal, pertroleum and natural gas). The fossil resources and phosphorus are imported from other states. Sources of potash exist in southwestern Colorado, although current production is insignificant. Additional supplies are available from southeastern Utah, where potash is mined exclusively.

The main source of organic fertilizer in Colorado is livestock manure. Dried manure comprised about 88 percent of the total organic commercial fertilizer sales in 1972 in the Mountain States; about 10 percent consisted of activated sewage sludge; the other two percent was composed of other sewage organics and tankage, and dried blood. Similar percentages are assumed to hold for Colorado (Reference 5).

There were 281,000 metric tons [309,551 tons] of fertilizer sold in Colorado in 1972, up from about 175,000 metric tons [193,000 tons] in 1965. During the same period, the commercial sale of natural organic materials dropped from 16,000 metric tons [18,000 tons] to 6,600 metric tons [8,000 tons].

Table 15. VALUE OF CROPS PRODUCED IN ADAMS COUNTY, 1972-1973

Crop	1972		1973	
	Value	%	Value	%
Wheat	$ 6,752,900	44	$13,768,000	61
Corn, grain and silage	2,310,000	15	2,467,100	11
Barley	832,000	6	763,500	3
Sorghum grain	25,100	--	35,700	--
Sugar beets	744,400	5	--	--
All other crops[a]	4,529,300	30	5,590,500	25
TOTAL	$15,193,900	100	$22,624,800	100

[a] Includes dry beans, rye, hay, potatoes, oats, broomcorn, fruits and vegetables.

Source: Comprehensive Plan: Adams County.

Table 16. LIVESTOCK ON FARMS, 1 JANUARY 1973, ADAMS COUNTY, RELATIVE TO ALL COLORADO COUNTIES

Livestock	Number	Ranking
Cattle and calves	70,000	13
Milk cows	5,000	3
Hogs and pigs	22,500	4
Stock sheep	4,300	25
Cattle on feed	40,000	5

Source: Comprehensive Plan: Adams County.

The fertilizer required for the agricultural economy of the state was in short supply, at the time of the release of the draft EIS. This situation was linked to fuel and natural gas shortages and to increase demand in this country and abroad; however, present supplies seem adequate. Future shortages related to the increasing scarcity of fossil fuels will undoubtably occur.

Urban/Rural Characteristics

The socio-economic characteristics of the Metro Denver service area differ greatly from the characteristics of the area proposed for the sludge drying and distribution center. This difference reflects the urban/rural contrast: Metro Denver serves the urbanized Metropolitan Denver area, while the proposed site is situated in rural Adams County. There are perhaps even greater differences between the eastern and western parts of Adams County than between Denver County and Adams County, as indicated in Table 17.

Table 17 shows some of the contrasts among socio-economic characteristics of the three areas (Reference 43). In 1972, about 95 percent of the population of Adams County was urban rather than rural, with approximately 65 percent of the population concentrated in five cities in the far western part of the county adjacent to Denver (Aurora, Northglenn, Commerce City, Thornton and Westminster). Census Tract 084 consists of that part of Adams County east of Box Elder Creek (roughly the eastern two-thirds of the county), the area in which the sludge drying and distribution center would be located.

Land Values

An appraisal of Site B-2 in 1976 by a private firm set its value site at $540,000. This sets the value of the land at about $700 ha [$280/acre] (Reference 132).

Market values fluctuate considerably, but the current market for land bought by a farmer in large tracts in the general area of the proposed project site is approximately $500/hectare [$200/acre] for dry farmland and $1,000/hectare [$400/acre] for farmland with wells adequate for irrigation (Reference 66).

Through speculation, often in anticipation of a special demand for a particular parcel, property values may rise as high as $5,000/hectare [$2,000/acre], or prices may be increased because of a transaction which involves a low downpayment (Reference 66). The recent trend in land values in the area is one of sporadic increases in property value. The general trend in Colorado shows a 25 percent

Table 17. CONTRASTING SOCIO-ECONOMIC CHARACTERISTICS

Characteristic	Criterion	Denver County	Adams County	Census tract 084[a]
Total population	Numbers of people	514,678	185,789	2,233
Mobility/stability	Lived in same house, 1965-1970	44.0%	46.6%	50.6%
Commuting patterns	Work in county of residence	78.1%	32.7%	69.4%
Education	High school graduates, 25+ yrs old	61.5%	62.7%	58.0%
	College graduates, 25+ yrs old	15.5%	8.6%	5.2%
Family size	Children born/women married, 35-44 yrs old	3.0	3.0	2.7
Income	Median family income	$ 9,654	$10,409	$ 6,374
Age	Median age	28.6	22.8	28.2
Farm population	Number of farm-related jobs: farmers, mgrs, foremen, workmen	1,020	1,613	277
	Farm and related jobs/100,000 population	198	868	1189

[a] Approximately the eastern two-thirds of Adams County.

Source: 1970 Census of Population and Housing (Reference 64); 1970 Census of Population (Reference 65).

increase in land value from 1972 to 1973, a 14 percent increase from 1973 to 1974 and a seven percent increase from 1974 to 1975 (Reference 66). Land values may change near the proposed site in response to a number of currently unpredictable factors, including changes in farm prices and the rate of growth of the Denver region.

Employment

The employment-generating facilities associated with the proposed project will be located in Adams County. The major employment classifications in Adams County are given in Table 18.

Table 18. ADAMS COUNTY EMPLOYMENT PATTERNS, 1973

Employment category	Number employed
Retail trade	8,700
Manufacturing	7,300
Contract construction	5,100
Services	4,900
Farm-related jobs (farmers, managers, foremen, workmen)	1,800
Wholesale trade	1,600
Transportation and other public utilities	1,600
Finance, insurance, real estate	1,200

Source: 1970 Census of Population (Reference 65); Adams County Information Service (Reference 43).

The Urad mine is one of the sites being evaluated as a sludge recycling area. The mine is one of three owned by Climax Molybdenum Company, which is the largest private employer in Colorado, employing 3,500 workers (Reference 41).

The unemployment rate in the eight-county Denver-Boulder Labor Market Area in September 1975 was 5.7 percent; the Adams County rate was 5.8 percent (Reference 67). The national rate at that time was eight to nine percent.

VISUAL AESTHETICS

The rural regions within the study area are characterized by a broad, rolling topography. While there are generally no particularly striking features in this agricultural area, an expansive and restful atmosphere gives the area a pleasant contrast to the urbanized areas to the west. Dryland farms bear relatively few signs of agricultural activity and thus do little to disturb the area's original prairie impression. Irrigated farms are more active; their green crops exist in greater variety and provide a more stimulating rural backdrop.

The Denver Parks provide a variety of well-maintained, attractive areas within the city. The 1,800 acres of parkland range from quiet, secluded neighborhood parks to the spacious City Park, which includes a number of lakes and provides a setting for many culutral and recreational activities.

To reach the mine reclamation site farther to the west, one leaves the flat, rural regions and climbs into the rugged, mountainous terrain more commonly associated with the Rocky Mountain region. The Urad Valley is one of the many high, scenic valleys along U.S. Highway 40, but its scenic value has been impaired by mine tailings deposited on the floor of the valley.

Specific descriptions of the environmental setting of the various representative sludge application areas are presented in Appendix E.

PUBLIC HEALTH

The agency charged with maintenance of the public health in Adams, Arapahoe and Douglas counties is the Tri-County District Health Department. This agency monitors the present Metro Denver sludge disposal operations at Lowry Bombing Range in Arapahoe County and would also monitor the health impacts of the proposed project. A project requiring a Certificate of Designation is subject to review by the Colorado Department of Health, who would have veto power over the project (Reference 78).

The U.S. Environmental Protection Agency takes public health impacts into consideration in awarding grant monies. These considerations are contained in the tentative guidelines presently being circulated for review before being formally released by EPA (Reference 79).

The Agricultural Research Service of the U.S. Department of Agriculture sets down criteria to ensure that heavy metals in sludge (zinc, copper, cadmium, etc.) will not harm plants or the soil. The U.S. Food and Drug Administration has yet to promulgate guidelines for control of levels of possibly harmful substances in sludge applied to crops which enter the human food chain.

87.a

SECTION IV

The principal features of Metro's proposed sludge management plan are described in this Section. Main features include anaerobic digesters, pipeline and pumping facilities, the drying/storage/distribution center and proposals for on-site irrigation and disposal. Metro is planning to market the sludge to farmers and other users. The type of uses considered and their general locations are described here. Discussion of recommended loading rates and limits based on research in each type of land use is presented.

SECTION IV

DESCRIPTION OF PROPOSED ACTION

Metro Denver's proposed sludge management plan involves treatment of sewage sludge at the District's Central Plant and pipeline transport to a sludge drying and distribution center 40 km [25 miles] east of the Metro Denver Central Plant. Air-dried and liquid sludges will be taken from the center and applied to the land in various ways. Each component in the proposed sludge management system is described in this Section. A predesign and site selection study was conducted for Metro Denver in 1974-75. The recommended plan is discussed in detail in the "Metro Denver District Sludge Management, Volume I - Summary Report and Volume III - Agricultural Reuse Predesign" (References 55 and 118). Excerpts from these reports are used extensively in this Section for the description of the proposed action.

SLUDGE TREATMENT

Raw sewage sludge is generally unacceptable for land application due to the problems of odors, vectors and disease transmission. These aesthetic and public health problems can be alleviated by stabilization of the putrescible organic material in the sludge. Sewage sludge at the Metro Denver Central Plant will be stabilized by anaerobic digestion. The Denver Northside Plant sludge is digested prior to conveyance to the Central Plant. This process will involve the decomposition of most of the organic materials by micro-organisms in the absence of oxygen. The sludge will be processed in mesophilic digesters with a constant temperature maintenance at 35°C [95°F] and continuous gas-diffusion mixing.

The digesters are designed for loadings of 2.1 kg of volatile suspended solids (VSS) per day per cubic meter of digester [0.13 lbs/day/cubic foot] and a 22 day digestion period. At the end of this detention period, 50 percent volatile solids destruction and three percent solids concentration should occur. Most of the organic material will be converted into water, methane, carbon dioxide and other gases. A comparison of changes in sewage sludge characteristics through anaerobic digestion is given in Table 19.

Table 19. CHANGES IN CHARACTERISTICS OF SEWAGE SLUDGES THROUGH DIGESTION[a]

Constituents	Concentration from treatment preceding analysis									
	Primary settling		Activated sludge Secondary settling		Calculated[b] Combined sludges		Mesophilic digestion		Thermophilic digestion	
	Range	Mean	Range	Mean	Mean		Range	Mean	Range	Mean
Total solids, %	4.25- 8.90	6.4	0.44- 0.89	0.69	4.02		1.15- 2.98	2.12	1.67- 3.64	2.35
Suspended solids, %	-	-	0.10- 0.79	0.58	-		1.04- 3.23	2.22	1.06- 3.67	2.49
Volatile solids, % of T.S.S.	72.0 -94.5	80.2	57.3 -92.0	73.1	79.8		35.8 -71.5	59.9	37.8 -70.5	62.0
Chemical oxygen demand, ppm	36,800-98,280	61,267	4,224-11,408	7,106	38,699		12,900-42,400	24,195	19,200-47,200	33,420
Total nitrogen, ppm	1,070- 2,734	2,066	481- 799	541	1,431		1,840- 2,173	2,000	1,516- 2,079	1,992
Organic nitrogen, ppm	340- 2,626	1,874	462- 580	512	1,30		720- 969	869	320- 790	697
Phosphate, ppm	1,237- 2,257	1,795	963- 1,360	1,148	1,525		1,250- 1,734	1,570	1,101- 1,697	1,604
Grease, ppm	8,544-13,916	11,080	248- 528	400	6,630		1,576- 2,672	1,981	2,468- 3,264	2,820
Alkalinity, ppm	1,000- 2,420	1,603	330- 520	430	1,114		4,900- 6,700	5,520	5,190- 7,900	6,190
	Dissolved	Suspended	Dissolved	Suspended	Dissolved	Suspended	Dissolved	Suspended	Dissolved	Suspended
Cadmium, ppm	0.02	2.48	0.03	0.77	0.02	1.77	0.02	2.98	0.02	2.78
Nickel, ppm	0.67	10.43	0.38	1.42	0.55	6.68	0.36	9.14	0.45	11.1
Lead, ppm	Total: 8.00		0.25	2.25	Total: 5.71		0.50	7.5	0.45	7.55
Silver, ppm	Total: 2.40		0.30	2.00	Total: 2.36		Total: 3.30		Total: 2.40	
Zinc, ppm	1.55	119	0.25	12.8	1.01	75	0.06	77.3	0.20	67.8
Copper, ppm	11	52	0.50	11.5	6.6	35	11	32	0.27	36.7
Arsenic, ppm	0.01	1.0	0	0.14	0.006	0.64	0.01	0.08	0.04	0.87
Chromium, ppm	0.09	45	0.07	16	0.08	33	0.06	50.3	0.15	52.5

[a] Typical ranges and means were obtained from data at the City of Los Angeles Hyperion Wastewater Treatment Plant.

[b] Primary to secondary sludge solids ratio 15:1; primary to secondary sludge flow ratio 1.4:1.

The example data are drawn from the Hyperion Wastewater Treatment Plant in Los Angeles which treats sludges with higher metal content than Metro Denver's and utilizes thermophilic digestion. While the changes in characteristics of sludges occur at a faster rate in thermophilic digestion, the change in characteristics is generally similar to that from a mesophilic process. However, it is expected that microorganisms (pathogens in particular) will not be reduced in numbers as effectively with the mesophilic process.

At the anticipated design loading, ten digesters would be required with a total volume of 2.4 million cubic feet. First, eight concrete anaerobic digesters with a total volume of 54,000 cu m [1.9 million cu ft] would be built to accommodate 1977 sludge loadings at the Central Plant of 2,047 cu m/day [547,000 gal/day]. These digesters have been constructed as part of the present Central Plant expansion. Two additional digesters would be constructed sometime prior to 1980 to handle the 1985 design capacity of 3,100 cu m/day [824,000 gal/day].

In the predesign study, it was assumed that all initial eight units would operate as primary digesters. Four of these units, however, have been designed with the flexibility of operating as secondary digesters for gravity thickening of the digested sludge.

Three existing sludge holding tanks at the Central Plant would be used in the sludge digestion and agricultural reuse system. One tank would provide storage for the undigested Central Plant sludge. Another tank would store the Central Plant sludge after it is digested as well as the Denver Northside digested sludge. The sludge in this latter tank would be pumped to the sludge drying and distribution center. The third tank would be used for storage of the liquid sludge in the event of some emergency in the system.

SLUDGE TRANSPORT SYSTEM

The liquid sludge would be transported from the Central Plant to the distribution center through two pipelines, 25 cm [10 in.] and 30 cm [12 in.] in diameter. Each pipe would be capable of handling 40 l/sec [600 gal/min] of sludge or secondary effluent. Secondary effluent would be pumped through the force mains to clean out solids deposits. At the distribution center the effluent would be used for irrigation, dust control and fire protection of on-site facilities.

The proposed pipeline route to the sludge distribution center site is shown on Figures 1 and 2. The criteria used for locating the route were length of route, elevation along the route and proximity to established rights-of-way for easy access to power lines. These criteria were used to minimize costs and environmental impacts. The pipeline will run parallel to the railroad tracks heading northeast from the District's plant and then turn eastward along the northern boundary of the Rocky Mountain Arsenal. From there the pipelines will turn east to the distribution center along Irondale Road.

A system of Central Plant pumps and booster pumps at an intermediate pump station would be used to produce the required head of 240 m [800 ft] to pump the material from the Central Plant to the distribution center. The Central Plant pumps would develop 120 m [400 ft] of head, and the additional 120 m [400 ft] would be supplied by the booster pumps.

All transport system pumps would be controlled from the Central Plant. Gauges and meters at both the Central Plant and distribution center would monitor the operation of the transport system.

SLUDGE DRYING AND DISTRIBUTION CENTER

Drying and Distribution Center Site Selection

The three potential sites for the drying and distribution center, shown on Figure 2, were compared to determine the best location on the basis of economic and environmental considerations. Factors examined in making the site selection are shown in an appendix to the Environmental Assessment for the Metropolitan Denver Sewage Disposal District Sludge Management (Volume IV) (Reference 8) and reproduced here in Appendix G.

The environmental factors investigated in comparing the sites included historic value of each site, climate, plant and animal ecology, traffic and aesthetic impacts, economic investment and land use. Land use was found to be the most distinguishing factor among the three sites. The least amount of project impact on present and potential land use would occur at site B-2. Both sites A and A-2 have the disadvantage of being located near an existing housing subdivision which is scheduled for future expansion. Because site B-2 is near the fewest number of private homes, location of the facility at that site would be more acceptable to the local community.

In an economic comparison conducted in Appendix A of "Agricultural Reuse Predesign" (Volume III), the present worth for 10 years of design, construction and operation for sites A, A-2 and B-2 is $11,948,000, $11,695,000 and $12,899,000, respectively.

Thus, on the basis of the economic comparison, site A-2 would be the preferred location, and site B-2 the least desirable location. However, site B-2 was recommended as the best location for the drying and distribution center primarily because it was not near any major residential development. The potential social problems associated with locating the distribution center near a subdivision far outweighed all other differences among the three sites. Solutions or compromises could be worked out for most of the environmental and economic problems. However, strong public opposition to the project would be difficult to resolve and could be detrimental to the success of the project. Locating the distribution center at site B-2 would minimize this problem. Furthermore, the projected location of a new regional airport near site B-2 comprises a highly compatible land use.

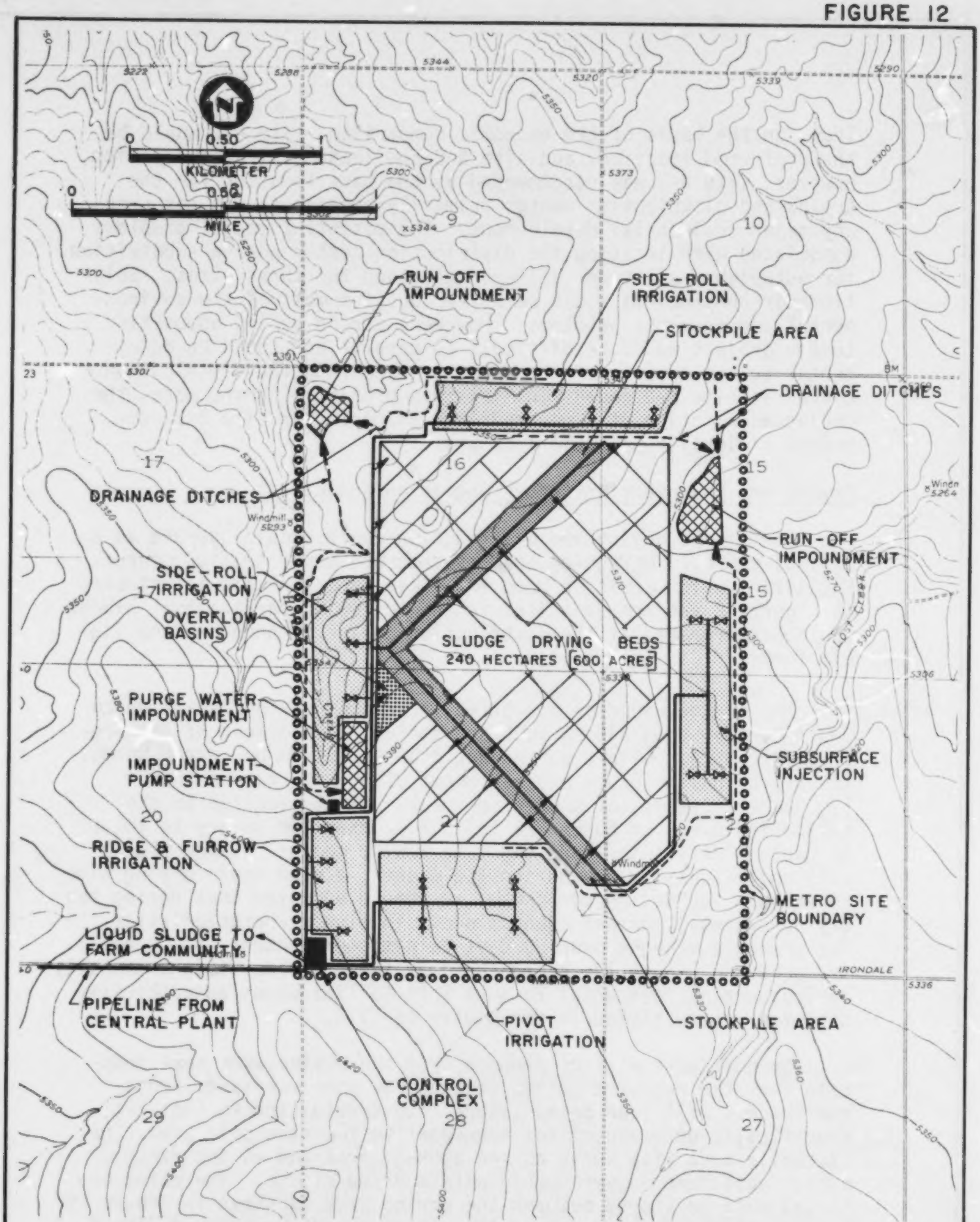
Drying and Distribution Center Operation and Layout

The sludge drying and distribution center would operate as a drying, storage, marketing and research and demonstration center. Facilities which would be used for these functions are illustrated on Figure 12 and are described in the following paragraphs. Sludge could be purchased at the distribution center in both dry and liquid forms.

The sludge would be air-dried in earthen drying basins which would occupy about 240 ha [600 ac] at full development of the project. The open, unlined basins would be separated by earth berms. The drying basins could process about 33,000 dry metric tons [36,000 short tons] of sludge per year. Sludge applied to the basins in layers of 60 cm [24 in] can be expected to dry to 40 to 50 percent solids in about eight to twelve months. Since sludge will not materially dry during the winter, a nine month drying time is assumed for design purposes. It should be noted that during the drying process, further changes occur in sludge characteristics. The probable changes over 50 days in nitrogen content, for example, are shown in Figure 13, as measured at the Colorado State University Agricultural Experimental Farm at Fort Collins using anaerobically digested liquid sludge in the winter of 1974.

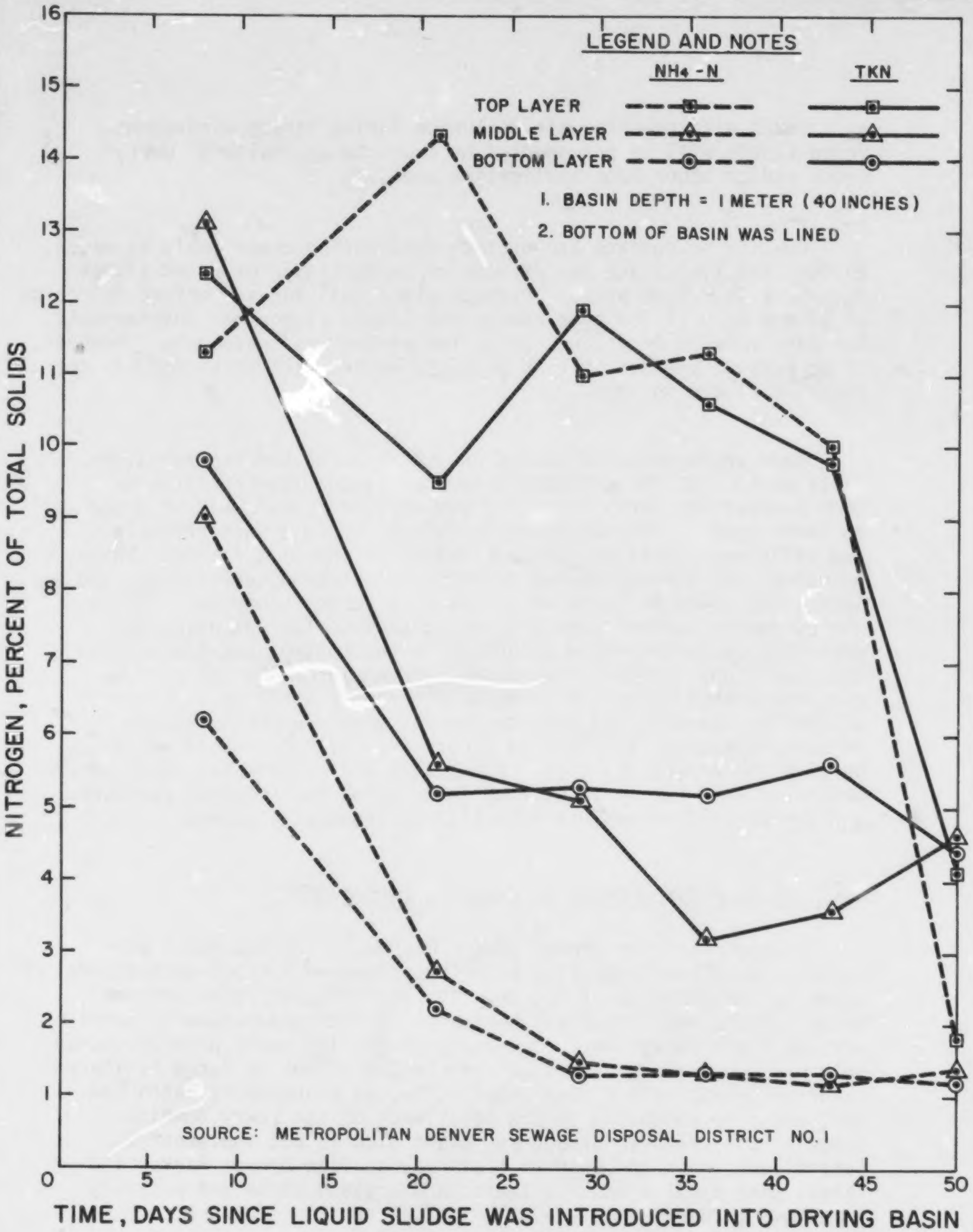
Dried sludge will be removed from the basins when test indicate that the required solids content has been achieved. Front-end loaders will load dried sludge into special trucks (not yet specifically determined) for transport to the stockpile area. The stockpile area will serve as the storage area and as the distribution point where users could obtain dried sludge. The dried material will be stored between the drying beds as shown in Figure 12. Fences will be erected around the entire solids drying and distribution center area to keep out grazing animals and wildlife. The capability for manual wetting of the stockpiles will be provided

FIGURE 12


0 0.50 KILOMETER
0 0.50 MILE
RUN-OFF IMPOUNDMENT
SIDE-ROLL IRRIGATION
STOCKPILE AREA
DRAINAGE DITCHES
DRAINAGE DITCHES
RUN-OFF IMPOUNDMENT
SIDE-ROLL IRRIGATION
OVERFLOW BASINS
SLUDGE DRYING BEDS
240 HECTARES [600 ACRES]
PURGE WATER IMPOUNDMENT
IMPOUNDMENT PUMP STATION
SUBSURFACE INJECTION
RIDGE & FURROW IRRIGATION
METRO SITE BOUNDARY
LIQUID SLUDGE TO FARM COMMUNITY
PIPELINE FROM CENTRAL PLANT
PIVOT IRRIGATION
STOCKPILE AREA
CONTROL COMPLEX
9
10
16
17
15
20
21
29
28
27
IRONDALE
Lost Creek

SOURCE: SLUDGE MANAGEMENT PLAN FOR METRO DENVER DISTRICT.

METROPOLITAN DENVER PROPOSED
SLUDGE DRYING AND DISTRIBUTION CENTER



SOURCE: METROPOLITAN DENVER SEWAGE DISPOSAL DISTRICT NO. 1

AMMONIA AND TOTAL KJELDAHL NITROGEN CONCENTRATION AS A PERCENT OF THE TOTAL SOLIDS CONCENTRATION IN THREE LAYERS IN AIR DRYING BASINS as a means of preventing air pollution during strong windstorms. Dried sludge will be transported by truck to agricultural users' farms and to other land application areas.

On-site subsurface and surface application areas could be used to test and illustrate the effects of using liquid or dried sludge for agricultural purposes. Present plans call for subsurface injection of sludge only if for some reason the liquid sludge was unacceptable for distribution or drying, or if the market was inadequate. However, it appears at present that an adequate market will exist for all the District sludge in 1985.

Land application of sludge on the research and demonstration plots would test the effects of various sludge loading rates on crop production. Both irrigated and dryland crops would be grown on these plots. Various control features would ensure reliable and efficient operation and maintenance of the distribution center. A control and administration building, a maintenance building, and a laboratory would be parts of the on-site control complex. All of the automatic controls and monitoring devices for operating the distribution center would be housed in the control and administration building. Another control feature would be the collection and impoundment of the on-site surface runoff water by a system of earthen channels and dams to prevent possible contamination of surface waters, as shown on Figure 12. Offsite runoff would be diverted around the site. Also, soil and groundwater would be monitored continually to provide information for research purposes. and for protection against potential environmental damage.

PROPOSED LAND APPLICATION OF SLUDGE BY METRO DENVER

The Metropolitan Denver Sewage Disposal District No. 1 proposes to make sludge available for recycling on various agricultural areas in the vicinity of Denver. The agricultural reuse program would involve controlled seasonal applications under careful nutrient and toxin management. Disposal landfilling would probably occur only under emergency conditions at the Lowry Bombing Range Sanitary Landfill. High-rate sludge application, as proposed by Metro Denver, would be conducted in the open lands of the Lowry Bombing Range if the proposed sludge recycling plan is not implemented. Controlled sludge application areas may include Denver Parks, sod farms, mine spoil areas, irrigated and dryland farms and possibly some home gardens.

It is envisioned that no single type of application will be used for the ultimate disposal of the entire sludge generated in Denver. More likely, a combination of two or more types of land application, with varying proportions from year to year (and greater variety in the years following the initial few years) will take place. Because of the varying environmental settings of the different sites and the different possible impacts of each type of land application, separate discussions of each type and the methods of application envisioned for those types are presented. Figure 3 shows potential areas for each category of sludge application. No definite contractual arrangements have yet been made for specific sludge recycling areas, nor are any contemplated at present.

SPECIALLY EQUIPPED TRUCK SPREADS SLUDGE ON FARMLAND

In the following paragraphs, the proposed sludge recycling areas and the present disposal operations at Lowry Bombing Range (the no-action alternative) are discussed with a view to recommended methods and rates of application and operation.

Sludge Recycling Areas

Denver Parks--

Over the past few years, some dried sludge (containing 20 to 30 percent solids) has been used in preparing topsoil for establishment of new city parks in Denver and other cities in the area. The stockpiled and air-dried sludge has been incorporated into topsoil at about 112 metric tons/ha [50 tons/ac] prior to spreading the topsoil on new park areas for seedbed preparation. The Parks Department now takes vacuum-filtered digested sludge and dries it near Stapleton Airport for use on parks.

In the future, if the proposed reuse scheme becomes operational, anaerobically digested and air-dried sludge will be spread during winter months on already established parks. It is expected that the sludge will be applied to the grass at the same total rate (112 metric tons/ha [50 tons/ac]) during the wintertime. The City and County of Denver Parks Department has received sludge free of charge in the past and expects to utilize up to a maximum of 4,500 metric tons [about 5,000 short tons] per year on that basis. However, if a charge is imposed or if the delivery responsibility is shifted to the recipient, a change in this projection may occur.

Other communities indicating interest in sludge application to park areas are Northglenn, Commerce City and Aurora. Parks in the Denver area which are potential sludge candidates are graphically shown in Figure 3.

Sod Farms--

Application of anaerobically digested air-dried sludge on sod farms will probably be conducted by broadcasting of the dry material using manure spreaders or similar equipment. The relatively frequent sprinkler irrigation, typical of such farms, will provide the necessary mechanism for moving sludge particles and soluble materials into the soil root zone.

With the cyclic removal of thin layers of soil during the harvest operations, residual sludge and its components--not used by plants--are also removed from the site and transported to the consumer. At the final destination, sludge materials in the sod root network and the soil carried with it are gradually dispersed into the soil and eventually taken up by plant root systems.

Representative locations of major sod farms in the Denver area are depicted in Figure 3.

Mine Spoil Sites--

In many parts of the Rocky Mountains, the natural landscape has been marred by large piles of mine tailings created in the process of extracting molybdenum and other elements from mined ores. Without a deliberate effort to reclaim these spoil areas and improve their potential productivity, these inert heaps may remain unvegetated for many decades. On some sites, where particle sizes are uniformly coarse (large gravel, boulders and rocks), larger particles may have to be crushed or finer materials imported before attempting to add organic materials.

For the example mine spoil site--the URAD mine near Berthoud Pass--it is expected that Climax Molybdenum will furnish the necessary trucks and other equipment needed for transporting and applying dried sludge. Sludge will be mixed with wood chips in equal proportions and applied at an initial rate of 45 metric tons/ha [20 tons/ac] of the sludge (90 metric tons/ha [40 tons/ac] of the mixture). It is planned to add another 22 metric tons/ha [10 tons/ac] of sludge within the first two years after the initial application. Thus, a total of 67 metric tons/ha [30 tons/ac] of sludge will be added to reclaimed spoil areas. It is expected that this application rate will prove to be lower than optimal for spoil reclamation. With a total spoil area of 50 ha [125 ac], this will amount to a total sludge dry solids utilization of 3,400 metric tons [3,800 tons] at this particular mine.

Another area of potential sludge usage is the Watkins Project, approximately 17 miles east of downtown Denver on Highway 70. The Watkins Project is a conceptual plan to develop largely untapped reserves of lignite coal near Denver. Under this scheme, the coal resource would be combined with solid wastes and converted (gasified) into pipeline quality natural gas. The energy source for operation of the coal mine, the coal gasification plants and reclamation and restoration programs, as envisioned by the Mintech Corporation, may potentially be derived from Denver sewage sludge and solid wastes. Briquettes pressed from mixtures of solid waste (garbage) and liquid sludge could supply approximately 20 percent of the fuel feedstock. Dried sludge may also be used as an alternate energy source.

The earliest projected date for project completion is 1981, depending upon various financial arrangements and approvals by State and Federal regulatory agencies.

Irrigated Farms--

Sludge application on irrigated farms will be the most sensitive of the agricultural reuse schemes, because of the intensive food crop production on such farms. It is important to note that the sludge application procedures and rates described here are those best suited for the specific site studied. Impacts discussed in Section V are similarly site specific. Therefore, an examination of the characteristics of each site is necessary prior to embarking upon a sludge application program. Such examination should include analyses of soil cation exchange capacity (C.E.C.), pH and background heavy metals.

At the present time, barnyard manure is used on many irrigated farms, particularly in sugarbeet fields. Conversion to use of sludge or supplementation of this material can be readily accomplished with existing equipment and procedures.

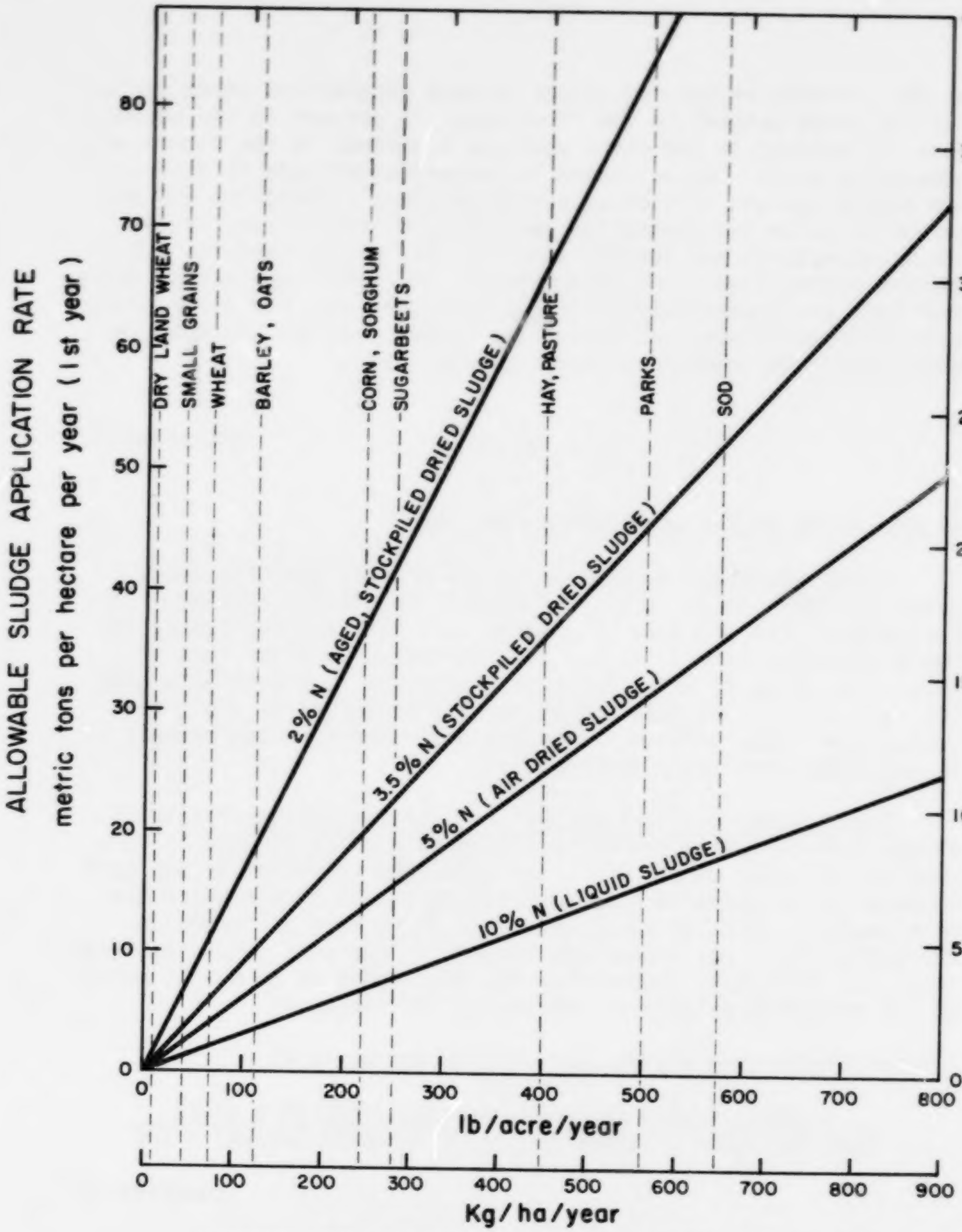
Annual Application Rate Limitations--It is expected that annual sludge application rates will be limited to the quantity which provides nitrogen in amounts that can be taken up by the crops grown on the farm. A formula of this general character requires a number of assumptions, regarding the basic parameters determining nitrogen balance. The more significant of these parameters are:

1. potential annual uptake of nitrogen by each crop, U, in kilograms per hectare per year
2. total nitrogen content of applied sludge, N as percent of solids
3. proportion of crop nitrogen removed from the land at harvest, c_1
4. percent of nitrogen which is mineralized (made available to plants) in a given year, c_2
5. total background nitrogen in soil, p, in metric tons per hectare

Using these values, annual application rate, R, in metric tons per hectare, is given by the formula:

$$R = \frac{c_1\ U}{1{,}000\ c_2\ N} - p \qquad \text{(Equation 1)}$$

A plot of this equation is shown on Figure 14, in which p is assumed to be zero. Under most conditions this is a reasonable assumption for the first year of sludge application. On a farm which has received sludge or other nitrogenous organic materials in past years, p can be approximated by assuming that 30 percent



UPTAKE OF MINERALIZED NITROGEN BY PLANTS

NOTE : ASSUMING $C_1 = 95\%$; $C_2 = 30\%$; $p = 0$

RELATIONSHIP BETWEEN ALLOWABLE SLUDGE APPLICATION RATE AND UPTAKE OF MINERALIZED NITROGEN FOR SLUDGES CONTAINING DIFFERENT AMOUNTS OF NITROGEN - PLOT OF EQUATION 1 of the nitrogen in applied sludge becomes mineralized (made available for plant uptake) in the first year, 15 percent in the second year, 10 percent in the third year and 5 percent in the fourth and succeeding years. While controlled experimental data in this area are rather sparse, this decay series provides a tentative and conservative guide for protection against over-application. Using these assumptions and further assuming that sludge contains 3.5 percent nitrogen on a dry weight basis, allowable application rates over time are graphically portrayed in Figure 15. For other sludges with different sludge concentrations (other than 3.5 percent) the plots should be adjusted proportionately, i.e.,

$$R_N = \frac{3.5}{N} R_{3.5} \qquad \text{(Equation 2)}$$

to obtain the proper application rate, R_N.

Sludge application rates which are greater than the rates given in Figure 15 for a given crop will result in leaching of excess mineralized nitrogen beyond the root zone and eventually to the groundwater table. It has been estimated by Pratt that it takes from 10 to 50 years for excess nitrogen to travel 30 m [100 ft] vertically in an unsaturated medium, depending on the intervening soil types present (Reference 96). The nitrogen balance is discussed more fully in Appendix D.

Total Sludge Application Surface Rate Limitation--The total sludge quantity which may be permitted on a piece of land is limited by the heavy metals which can safely be tolerated in the soil. A quantitative guide on the tolerable amount of sludge which can be allowed is that the total amount of heavy metals introduced therewith should not exceed ten percent of the soil cation exchange capacity. A formula proposed by the EPA (modified to metric units) in the tentative guidelines (Reference 79) suggests:

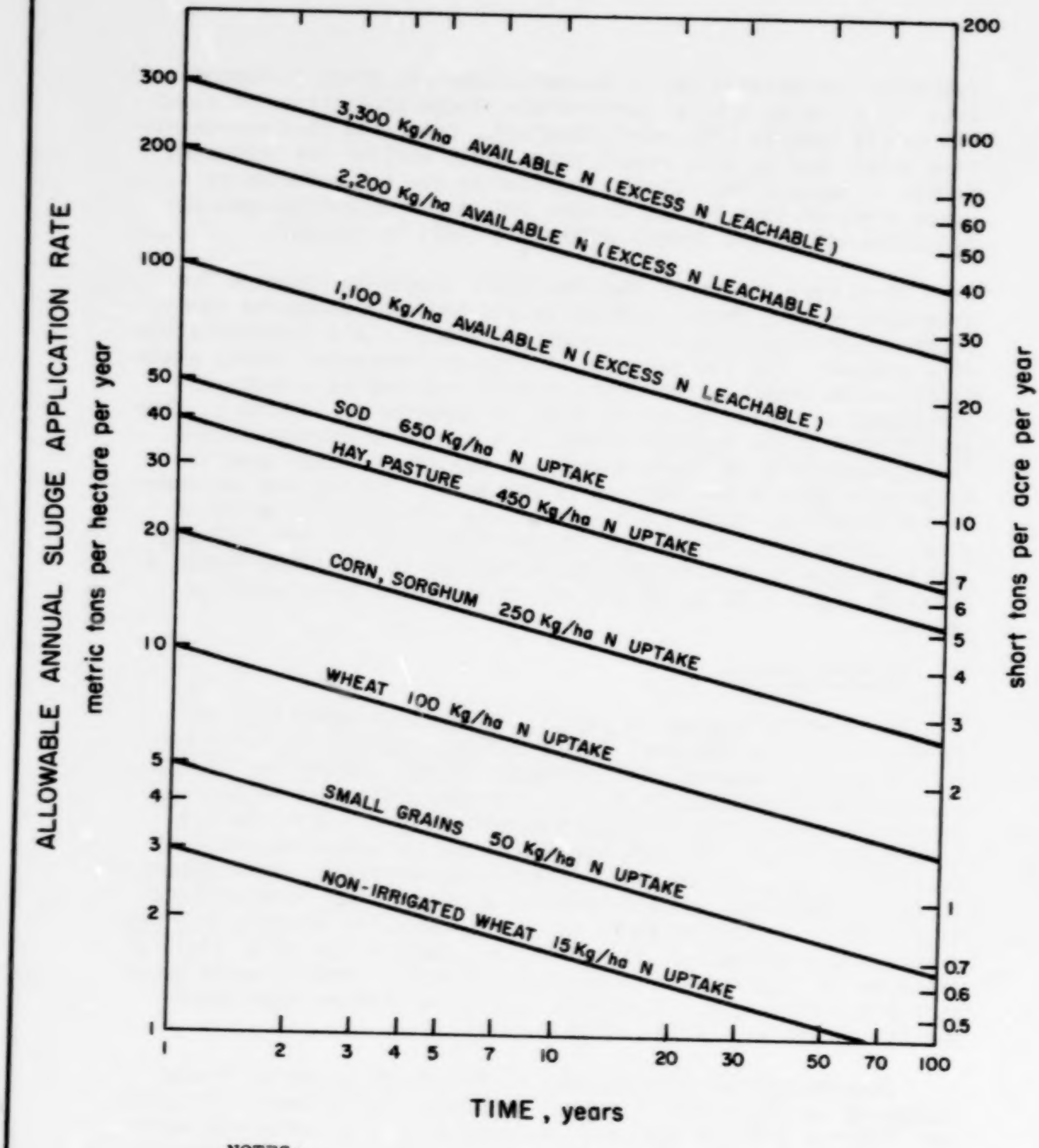
Total Sludge (dry solids, metric tons per hectare) =

$$\frac{73{,}000 \times \text{Cation Exchange Capacity (meq/100 g soil)}}{\text{Zinc (mg/kg)} + 2\ \text{Copper (mg/kg)} + 4\ \text{Nickel (mg/kg)} - 200}$$

(Equation 3)

The implicit assumption of this formula is that copper is twice as toxic as zinc and nickel is four times as toxic. Soils that might receive Denver sludge in Arapahoe or Adams County may have a cation exchange capacity of 20 meq/100 g. Typically, Denver sludge contains 1,145 mg/kg zinc, 808 mg/kg copper and 282 mg/kg nickel

FIGURE 15



NOTES:

1. ASSUMING 3.5% N IN SLUDGE WITH 0.30, 0.15, 0.10, 0.05 .... DECAY SERIES FROM YEAR 1 ON.
2. RATES NECESSARY TO MINERALIZE (MAKE AVAILABLE) CONSTANT NITROGEN QUANTITIES FOR VARIOUS CROPS AND/OR LEACHING OF EXCESS N TO GROUNDWATER.
3. 1 Kg/ha = 0.892 lb/ac

ANNUAL SLUDGE APPLICATION RATES

(chemical characteristics of Denver sludge are given in Appendix D). Equation 3 yields a total permissible sludge application of about 400 metric tons/ha [180 short tons/ac]. Comparing this representative total loading with annual rates given earlier for irrigated farms, it appears that sludge application can be conducted on a given piece of land for 20 to over 100 years (depending upon application and uptake rates) before the limit is reached.

It is very important that the limit should be computed for each soil on each farm. Average values and representative conditions can be deceiving with respect to actual field implementation of a project. For the purposes of this environmental impact statement, values found on the farms studied are used as a means of assessment of impact on those sites as reported in Section V. The specificity of the impacts to the site cannot be overemphasized. The applicability of these impacts to the entire study area is valid only insofar as planning is concerned. Design and implementation should be viewed from an entirely site-specific point of view. Using safe average application rates, if all the 1985 projected sludge quantities were to be applied to irrigated farms, a total of about 3,000 ha [7,000 ac] of irrigated farms would be needed.

Dryland Farms--

As noted in Figures 14 and 15, wheat grown under dryland farming practices uses very little nitrogen due to the lower production rates, compared with irrigated crops. Therefore, sludge application rates consistent with nitrogen uptake are rather low, ranging from less than one to three metric tons/ha [0.3 to 1.5 tons/ac] per year. At such low rates, rather extensive areas of application and, consequently, greatly increased operation expenditures are involved. On the other hand, due to the lower application rates, the dryland farms can be utilized for sludge reuse over a much prolonged period (over 300 years) before the total limit of heavy metals loading is reached. Furthermore, impacts would occur at a proportionately slower rate, providing greater opportunity for mitigation and amelioration.

Experimentation with methods of direct injection of liquid sludge at various depths has been conducted in the Denver-Boulder-Fort Collins area and equipment is available from commercial manufacturers (References 97 and 98). These methods have promise particularly for dryland farms with the lower application rate requirements. The effort involved in such methods is about equal to land scarification procedures widely utilized by farmers for water conservation. Sludge injectors achieve both functions in the same operation (Reference 97).

Application of air-dried sludge with manure spreaders or other similar equipment can be controlled to achieve proper application rates. Due to the relatively low rainfall rates and minimal cultivation processes in the dry-farmed areas, it is expected that incorporation of sludge within the soil root zone will be a rather slow process; loss of nitrogen to volatilization would be greater and the rate of breakdown of organic matter would be accelerated.

If all the 1985 projected sludge quantities were to be applied to dryland farms within safe application rates, a total of about 43,000 ha [100,000 ac] of non-irrigated farmland would be needed. If non-cultivated range land is to be included in sludge application, adequate areas exist within reasonable distances from the proposed distribution center.

Home Gardens--

The dried sludge could possibly be made available to the general public for use in home gardens. Users would purchase the sludge at the distribution center and apply it to ornamental plants, such as lawns and flowers. Although highly unadvisable, home gardeners may choose to apply sludge to vegetable gardens. Metro Denver could recommend appropriate usages of the sludge, similar to the criteria for irrigated farmlands, but would not be able to control or restrict ultimate uses of the sludge by the home gardener once the material is in his or her possession. Metro Denver also contemplates marketing the dried sludge (presumably fortified and sanitized) in bags for use by home gardeners in a similar fashion to the Milwaukee "Milorganite" and the Rhode Island "Organiform."

Sludge Disposal at Lowry Bombing Range (No Action)

The present sludge disposal practice involves a large-scale trucking operation from the Metro Denver Central Plant 40 km [25 mi] southeast to the Lowry Bombing Range.

For the high-rate sludge applications, the transfer trucks are unloaded on a special ramp at the Bombing Range into an enclosed hopper which in turn drains into smaller spreader trucks. The spreader trucks convey the dewatered (10 to 16 percent solids) sludge to the application areas where sludge is dumped in a uniform layer (about 15 cm [6 in.] thick) atop the ground surface and left to dry partially. The sludge is later plowed into the topsoil using moldboard plows pulled by a track-type tractor along the contours. Alternate contour strips are used to plow in the sludge while the intervening strips are cropped and used for pasture. A given contour strip receives sludge in this manner once every nine months at a rate of 67 metric ton/ha/yr [30 ton/ac/year]. As of 1977, each contour had received 459 metric tons/ha

(205 tons/acre). It is expected that if the agricultural reuse plan is fully implemented, disposal operations in the Lowry Bombing Range will be phased out.

SLUDGE IS SPREAD ON LOWRY BOMBING RANGE BEFORE DISCING

During winter months when land application becomes impeded by ice and snow on the ground, this operation is temporarily replaced by direct dumping of the sludge directly onto the soil surface and intermixing with soil at a ratio of five parts soil to one part sludge.

Sludge Landfilling--

Landfilling sludge along with other municipal solid wastes is a widely accepted practice, generally used for ultimate disposal of the solid wastes. Typically, partially dried sludge is dumped into the landfill and covered with other refuse. However, under well-managed sanitary landfilling procedures--increasingly in use in communities across the country--strict operating techniques are followed. Foremost among these techniques is a sound site selection process in which the environmental implications of candidate sites are exhaustively researched and compared. The U.S. Environmental Protection Agency has published a recent design and operation manual incorporating site selection, construction, operation and maintenance procedures (Reference 98). The methods and provisions standard on truly sanitary landfills are aimed at odor control, protection of public health, groundwater quality protection and prevention of various hazards. Monitoring provisions are aimed at determination of long-term impacts and early warning of adverse impacts. At the Lowry landfill, sludge disposal is expected to occur only during emergency periods when the normal operations are temporarily disrupted. Also, if the proposed sludge recycling plan is somehow aborted, and if Metro Denver is also barred from landspreading at the Lowry Bombing Range, it is possible that sanitary landfilling would be the reasonable alternative, at least in the short run. Metro expects that incineration would be chosen as the long-term solution.

SECTION V

This Section is the core of the EIS. It is here that the impacts of the proposed action are presented and discussed.

Because of the highly site-specific nature of the impacts, this Section is organized to emphasize the most important issues likely to arise at the most vulnerable sites. It is divided into three main parts. First, impacts expected during the processing, transfer, drying and stockpiling of the sludge are analyzed. Second, impacts at the land application sites (sludge recycling areas) are presented. Finally, impacts at the Lowry land disposal and landfill--which comprises the "no-action" alternative--are discussed.

Throughout, an attempt has been made to present the impacted environmental parameters and criteria in descending order of importance and intensity of impact, as perceived under the existing state of knowledge and as judged from the perspective of overall human welfare. A great deal of research in the field of land application of sludge is currently in progress and is planned for the future. Therefore, many of the stated impacts must necessarily be considered tentative in intensity and, in some cases, in magnitude and direction, as well.

SECTION V

ENVIRONMENTAL IMPACTS OF THE PROPOSED ACTION

INTRODUCTION

The Metro Denver sludge management plan, proposing the recycling of organic solids on land, is a relatively complex scheme involving several treatment subsystems and numerous different types of application sites. Such complexity and diversity gives rise to different types and intensities of impact, necessitating separate and distinct evaluation in the decision-making process. The reader who is interested in only one type of application site, under a given local condition, is cautioned to read this draft EIS with a special view to the specific sites and conditions discussed under each impact category. In the present draft, impacts are arranged in order of general severity and with particular reference to the sites of sludge application where they will be encountered.

IMPACT OF SLUDGE PROCESSING, TRANSFER, DRYING AND DISTRIBUTION

The environmental impact of the proposed action was partially assessed in the facilities planning process and reported in February 1975 (Reference 8). A summary of environmental impacts of sludge drying and distribution activities at the alternative sites, prepared by the facilities planners (CH2M Hill) is presented in Appendix G. Impacts attributable to the reocmmended sludge drying and distribution site (B2) are summarized in this Section.

Impacts of processing and transfer (pipeline) will be rather temporary and slight compared to those of the sludge drying/distribution site and those at the application sites.

Soil Loss

The excavation of 240 hectares [600 acres] of land to 1.5-m [5-ft] depth for the drying basins would effectively disturb all soil in this large area. Even though the disturbed soil mass would remain at the drying/distribution site, soil profile characteristics, structure and other physical properties would be so thoroughly destroyed or modified that an agricultural substratum would no longer exist. Furthermore, the soil mass thus removed would cover over other soil areas, gradually changing their physical, chemical and microbiological characteristics. Thus, an irretrievable loss of the soil resource from the site would occur.

Soils in the proposed drying/distribution site are largely in soil capability unit III-e (irrigated) or IV-e (nonirrigated). This indicates that, with a moderate degree of management control (especially to prevent erosion), the soils can be generally productive (particularly under irrigation). Soil impacts arising from experimental programs on the distribution site will be highly variable due to the wide range of application rates and methods typically used in a controlled experiment. It is expected that these experiments will be conducted with adequate monitoring of the various sludge components and environmental parameters during and beyond the experimental period. Results obtained from monitoring programs should provide the necessary information for minimizing and mitigating adverse impacts. The size of the experimental areas will be generally limited, and accumulations of excess quantities of heavy metals in plots receiving high application rates will eventually be dispersed, in part to surrounding soils (by cultivation practices) and in part to underlying strata.

The impacts of sludge reuse on agricultural land *per se* are discussed in later parts of this Section. Many of the statements made with reference to off-site impacts are equally applicable to conditions on the distribution site insofar as irrigated crop production is concerned.

Water

Groundwater Quality--

Due to the low permeability of soils in the distribution site, and the proposed basin lining, it is expected that water movement toward the groundwater reservoir will be very slow. Notwithstanding the slow initial rates of water (and sludge leachate) movement and the further clogging of soil particles, salt-laden water will eventually move past the upper soil strata. In time, this drained water and the solutes it carries will percolate into the water table and deteriorate groundwater quality. It is expected that the extent of groundwater pollution from this source will be significant considering the proposed 240 hectares [600 acres] of sludge drying basins. With a total dissolved solids concentration of 3,000 to 6,000 mg/l, the percolate is a threat to groundwater quality. Both the inorganic components and the stable organic portion of this leachate can damage the groundwater quality and thus gradually reduce beneficial uses of the water. The contamination of groundwater by nitrates is discussed under Public Health, below.

The soils in the proposed drying basins have a permeability of 3.3×10^{-4} to 1.3×10^{-3} cm/sec [0.008 to 0.03 in/hr]. Those soils with higher clay contents can be compacted to give a permeability of 1.0×10^{-7} cm/sec. Metro will be required by EPA to line all the basins with a layer of clay about 30 cm [1 ft] thick compacted to provide this permeability. This clay layer will be covered by sand or a similar cover material to prevent the clay from drying and cracking and to prevent damage during sludge removal operations.

Assuming that at any given time, half the basins are wet enough to release water for percolation, and assuming a total dissolved solids concentration of 5,000 mg/l, the quantity of leachate and salts moving toward the groundwater can be calculated. This amounts to about 38,000 cu m [1.3 million cu ft] of leachate carrying almost 190 mt/yr [210 tons/yr] of salts towards the groundwater table. This estimate is conservative, because it is quite likely that clogging of the soil by sludge particles will decrease the permeability to below this level. Even so a substantial quantity of leachate will move slowly toward the groundwater. Because of the slow rate of leachate movement, it will take 20 to 100 years for the water to reach the groundwater table, and a similar length of time to terminate this pollution. Thus, a lack of evidence of water pollution in the initial decades of operation cannot be reviewed as a sign of absence of impact. The groundwater mound eventually created will move horizontally and may affect wells in the vicinity.

Because of the potential severity of this impact, more data has been collected and analyzed since the release of the draft EIS. This analysis is presented in Volume II, Issues II- II2.

Other, partial, solutions include separation of decant, use of underdrains, pumping leachate from the ground and vacuum filtration of the sludge at the site before air drying. Mitigation measures against this severe impact are discussed in Section VI. Monitoring of leaching water quality and movement rates will be necessary.

Surface Water Quality--

Surface water protection will be effectively provided with the provision of drainage channels and earthen dams with adequate impoundment areas. These features have already been incorporated into the facilities plan for the drying and distribution area. Provision is made for analysis of impounded water for BOD, COD, biological indicators, nitrogen, total dissolved solids and other parameters, as set forth by agencies regulating discharges to surface water. Contaminated water would not be discharged to streams but would instead be used for surface irrigation (See above for groundwater quality effects). An exception could occur under extreme rainfall events (See Volume II, Issue II-6.

Water Rights--

In the process of transporting liquid sludge to the drying and distribution center, and during the periods of purging the pipelines with secondary effluent, about 1.1 - 1.7 mgd of water will be carried from the Central Plant to the Adams County Site. This is an increase over the approximately 130,000 gpd currently disposed at Lowry, but will still be less than 1 percent of the total plant discharge. It is anticipated that this removal of water will have some impact on appropriations downstream of the Central Plant discharge into the South Platte River. Under the existing system of appropriations, the treated and discharged sewage would belong to senior consumptive users downstream. However, under Colorado Supreme Court decisions, water transferred interbasin belongs to the diverter and can thus be reused. In this particular case, the Denver Water Board is the owner of the water transferred from the western slopes and will presumably allow Metro to use these additional waters as part of the treatment process. This issue is discussed in Volume II, Issue I-3.

Public Health

General--

Biological health hazards associated with sludge include pathogenic bacteria, viruses and parasites which may have survived the initial treatment process. The major bacterial diseases have been controlled well by traditional treatment processes. Statements about viral health problems must be more guarded and uncertain because of the difficulty in measuring viruses and the lack of standards for virus levels. In general, however, viruses are more short-lived than bacterial pathogens (References 39,80). Intestinal parasites may also be present in various forms in the sludge. Parasites and their eggs or cysts are only partially destroyed by traditional treatment processes. Other biological hazards associated with sludge are such disease-carrying vectors as flies, mosquitoes and rats.

Threats to health from chemicals with the sludge are generally chronic and indirect. Before the chemicals can reach the human body, they usually pass through at least two biological systems (plants and livestock); acute effects can be noted at these intermediate stages. The treatment process itself is a relatively sensitive biological system which can be upset at the activated sludge or anaerobic digestion stage if high concentrations of certain elements enter the system. Chemicals applied to the soils would affect the crops if they built up to dangerous levels. Present standards for heavy metals are based on determinations of the levels at which there is toxicity to plants (Reference 79). The human health effects of long-term, low-level consumption of these materials cannot be determined at this time. Therefore, potential adverse effects on human health cannot be overemphasized. Traditional sludge treatment processes do not reduce hazards to human health from heavy metals in the sludge. An interim primary standard has been established by the EPA for nitrates at 45 ppm (as nitrate) in drinking water supplies. If levels are kept below this threshold, a safe water supply is generally presumed. Regulations also exist to control the levels of persistent organic chemicals in certain components of the food chain. (See Volume II, Issue V-1.)

Health Protective Factors Associated with Sludge Management--

There are a number of factors which help to ensure that the potential health hazards associated with sludge will not be realized to the extent of creating actual health problems. The anaerobic digestion process destroys many of the human pathogens. Fecal coliforms, an indicator of pathogens, are reduced by 97 percent or more in a well-run anaerobic digester (Reference 79). Anaerobically digested sludge is generally considered biologically safe to use on farm crops without further treatment (Reference 81). Eggs and cysts of enteric parasites are able to survive the digestion process and remain alive for relatively long periods of time. The subsequent drying and soil incorporation processes are deadly to pathogens due to the exposure to ultraviolet light, desiccation and unsuccessful competition with the indigenous soil organisms. However, many parasites have long survival periods in the soil in cyst form or in the egg stage. Long-term storage of sludge is an effective reducer of pathogenic organisms (Reference 82). Storage of liquid digested sludge for 60 days at 20°C [68°F] or 120 days at 4°C [40°F] has been reported to be a successful pathogen reduction measure (Reference 79).

Pathogens--

Because potential hazards exist in the use of recycled, digested sludge, proper precautionary measures must be provided to assure that no significant harm to human health will result from this practice (Reference 39).

Pathogenic microorganisms will not pose a significant public health threat at the distribution site if the proposed project is operated as designed. The project will include a soil and groundwater monitoring system to monitor environmental quality. Six onsite wells around the perimeter of the drying site and other nearby wells will be used to monitor approximately 15 biological and chemical parameters.

The survival times of various pathogens associated with sewage sludge are given in Table 20. *Ascaris* ova (eggs of a parasitic worm) are particularly long-lived and thus are good indicators for monitoring the general sanitary quality of the sludge. *Salmonella*, relatively common pathogenic microorganisms, are also

Table 20. SURVIVAL TIMES OF PATHOGENIC MICROORGANISMS IN VARIOUS MEDIA

Organism	Medium	Type of application	Survival time
Ascaris ova	soil	not stated	2.5 years
	soil	sewage	up to 7 years[a]
	plants and fruits	AC[b]	1 month
Cholera vibrios	spinach, lettuce	AC	22 - 29 days
	cucumbers	AC	7 days
	non-acid vegetables--onions, garlic, oranges, lemons, lentils, grapes	AC	2 days
	rice and dates	infected feces	hours to 3 days
Endamoeba histolytica cysts	river water	AC	8 - 40 days
	soil	AC	8 days
	tomatoes	AC	18 - 42 hours
	lettuce	AC	18 hours
Enteric viruses	roots of bean plants	AC	at least 4 days
	soil	AC	12 days
	tomato and pea roots	AC	4 - 6 days
Hookworm larvae	soil	infected feces	6 weeks
Leptospira	river water	AC	5 - 6 days
	soil	AC	15 - 43 days
Salmonella typhi	dates	AC	68 days
	harvested fruits	AC	3 days
	apples, peats, grapes	AC	24 - 48 hours
	strawberries	AC	6 hours
	soil	AC	74 days
	soil	AC	70 days
	soil	AC	at least 5 days
	pea plant stems	AC	14 days
	radish plant stems	AC	4 days
	soil	AC	up to 20 days
	lettuce and endive	AC	1 - 3 days

Table 20 (continued). SURVIVAL TIMES OF PATHOGENIC ORGANISMS IN VARIOUS MEDIA

Organism	Medium	Type of application	Survival time
	soil	AC	2 - 110 days
	soil	AC	several months
	lettuce	infected feces	18 days
	radishes	infected feces	53 days
	soil	infected feces	74 days
	soil	AC	5 - 19 days
	soil	AC	70 - 80 days
	cress, lettuce, and radishes	AC	3 weeks
	lake water	AC	3 - 5 days
Salmonella, other than typhi	soil	AC	15 - 70 days
	vegetables	AC	2 - 7 weeks
	tomatoes	AC	less than 7 days
	soil	sprinkled with domestic sewage	40 days
	potatoes	sprinkled with domestic sewage	40 days
	carrots	sprinkled with domestic sewage	10 days
	cabbage and gooseberries	sprinkled with domestic sewage	4 days
Shigella	streams	not stated	30 minutes - 4 days
	harvested fruits	AC	minutes - 5 days
	market tomatoes	AC	at least 2 days
	market apples	AC	at least 6 days
	tomatoes	AC	2 - 7 days
Tubercle bacilli	soil	AC	6 months
	grass	AC	14 - 49 days
	sewage	?	3 months
	soil	?	6 months

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[a] Under warm, moist conditions not encountered in the Denver area.

[b] AC = Artificial Contamination

Source: Evaluation of Municipal Sewage Treatment Alternatives (Reference 80).

fairly hardy and therefore good indicators for monitoring the safety of the sludge.

Because of the remoteness of the site, human exposure to the drying sludge will be limited, further ensuring that no significant health impacts will result from the proposed project. However, public access to the drying beds should be limited while the sludge is drying.

An adequate soil barrier/filter exists for protection of the groundwater from any pathogenic microorganisms in the sludge. Surface water runoff will be contained behind earthen dams on sites generally above the present water table, and access to this water will be controlled to bar potential health and safety problems.

Nitrates--

It is probable that significant quantities of nitrogen, in the soluble nitrate form, will move with the leachate water from the bottom of the sludge drying basins toward the groundwater table. The precise quantity and rate of movement of the nitrates depend on several factors (denitrification rates under anaerobic conditions, mineralization of organic nitrogen forms by microorganisms, oxidation of the ammonia form under aerobic conditions, etc.), each of which may be occurring at different times and places in the basins at different rates. Once nitrate begins to migrate beneath the basins, it will remain unchanged and may gradually increase in concentration in the groundwater reservoir, eventually exceeding the 45 mg/l standard. High nitrate (NO_3^-) concentrations in drinking water supplies have been linked to methemoglobinemia, a rare "blue baby" disease resulting from reduction of the oxygen-transfer capacity of blood in infants. The problem of nitrate, coupled with the other salts discussed above under groundwater quality, can be reduced by lining the basins and other measures enumerated.

Vectors--

Gnats, flies and mosquitoes are the most common vectors of pathogens expected to be present in the vicinity of the drying basins. It is important that qualified specialist entomologists be consulted for the identification of specific species of insects that will emerge in the basins. While gnats and flies will remain within one km [~0.6 mile] of the basin boundaries, mosquitoes can travel (even under severe wind conditions) up to 40 km [25 miles] away. Mosquitoes and some species of flies can transmit certain diseases; hence, it is important that integrated insect control measures be instituted with a view to maximizing natural control mechanisms. The drying basins (240 hectares [600 acres] in size) will provide a large, permanent ecosystem with a wide range of moisture, food supply, breeding environments and surrounding vegetation. It is difficult to predict the actual invertebrate species that will inhabit this new ecosystem. However, it is possible that a few species will predominate in the absence of natural enemies. Only after accurate identification of the prevalent species can proper control measures be recommended. Hence, consultation with specialist entomologists is important at the initial stages of operation of drying basins. It may be necessary to add safe insecticides (such as organophosphates) to sludge at the treatment plant.

Experimental sites for liquid sludge application may also attract some insects and require control measures. Vectors such as rates and mice are usually not attracted to drying basins or to stockpile areas, but small burrowing animals will inhabit the basins. The proposed activities in the experimental areas are therefore not expected to influence either the presence or the size of population of such vectors.

Loss of Habitat

Animal species diversity at the proposed site will be somewhat reduced due to the removal of habitat during the construction of facilities and the excavation of vast areas for the sludge drying basins. Some species, including mice, voles and rabbits, may return to cultivated portions of the site when crops are growing. Some of the birds presently found on the proposed site may return if the level of human activity and the types of crops grown in these areas are not incompatible with their resting and feeding requirements. At the time of facilities planning investigations, consultants found "no nesting areas which might be disturbed" (Reference 8). The disturbance to vegetation along the 40-km [25-mile] pipeline and within the 800-hectare [2,000-acre] distribution site would not be of a drastic nature because most native vegetation has long been replaced by farming. Vegetation will be readily restored along the pipeline. At the distribution center, all vegetation at the site of the drying basins and stockpile area will be removed for the indefinite duration of the project. At the experimental areas, a presumably well-managed farming operation will replace the existing dryland farms.

Air Quality

The proposed project is not expected to cause a significant air quality impact on the alternative drying and distribution center sites during any but the most severe windstorms. (Odors are discussed as a separate topic in the pages following.)

During operation of the sludge drying center, considerable dust will originate primarily from vehicles driving on the dirt roads of the site. A problem lesser in magnitude but perhaps greater in public awareness is the dust which will be blown from the dried sludge piles. Because the sludge particles will have been thoroughly dried before becoming airborne, little odorous, volatile material will be present and pathogenic organisms will have been largely desiccated. However, spores and certain parasite eggs can survive in dry conditions for relatively long periods.

Normal winds will not spread significant amounts of dried sludge, though the strong (over 11 mps [24 mph]) winds which occasionally occur (during about two percent of the year) will spread the dried material, probably to the east or south (see Figure 9 for wind distribution patterns). It is difficult to estimate the amount of material blown during such winds. During most wind storms, the contributions from the sludge piles probably will not be quantitatively or qualitatively significant because of the cohesive, fibrous nature of the dried stockpiled material.

Air pollutants generated during transport and delivery of the dried sludge will not be of great enough quantity to significantly affect air quality. Impacts on air quality were determined assuming "worst case" conditions during peak periods: 30 truck trips/day and 200-km [120-mile] maximum roundtrip (Reference 77). From these figures and emission factors appropriate for the trucks (Reference 99), it is calculated that the maximum amounts of air pollutants generated during the spring and fall peak delivery periods are: hydrocarbons, 10 kg/day [23 lb/day]; carbon monoxide, 70 kg/day [150 lb/day]; nitrogen oxides, 110 kg/day [240 lb/day]. This will not cause a significant air quality impact, being about 0.03 percent of the pollutants emitted daily in Air Quality Control Region 2 (see Figure 8) (Reference 38).

Ammonia nitrogen (as N) accounts for three to four percent of the dry weight of the liquid sludge (Reference 55); 50 percent of this will be lost to the atmosphere during drying (Reference 88). On the basis of design sludge quantities, this amounts to approximately 620 metric tons [683 tons] per year of nitrogen-containing gases emitted. Liquid sludge loses about one-fourth as much ammonia nitrogen and therefore will emit less of this material to the air. These emissions have caused no known air quality problems in similar operations in Los Angeles County, California (Reference 100). It is doubtful that this loss in ammonia nitrogen will have a significant effect on air quality (Reference 101).

Because there is no air quality standard in Colorado for ammonia emissions, odor is the only parameter of concern with regard to this gas. An emission permit is required from the Air Pollution Control Division of the Colorado Department of Health under Regulation No. 2, promulgated by the Colorado Air Pollution Control Commission. Included in this permit would be a definitive plan for the control of odorous emissions. In addition, a complete inventory of quantities and rates of emission is required for all odorous compounds being emitted from the site. (Odor conditions are described separately below, and are discussed in Vol.II, Issue II-3).

The Department of Health further stipulates that significant emissions be modeled to estimate maximum concentrations and their locations downwind of the site. Similarly, it will be necessary to include a plan for the control of fugitive dust.

Odor--

Two sets of observations have been gathered on odors which might possibly enter the environment surrounding the proposed sludge drying and distribution center. One test was carried out by the Metro Denver staff in cooperation with Colorado State University on a system similar to the proposed new system. A second set of observations of interest was gathered by the Tri-County District Health Department on the sludge drying system presently operating at the abandoned Lowry Bombing Range.

In the first test, the Metro Denver District staff constructed and monitored six 8-m by 9-m [25-ft by 30-ft] sludge drying basins at the Colorado State University research farm at Fort Collins. A panel of Colorado State University faculty members and wastewater treatment plant operators was assembled. The odor tests were taken within a few meters of the basins over a period of 6 to 12 months. The panel was asked to describe the odor level in terms of the following numerical rating system:

0 - undetectable
1 - faintly detectable
2 - detectable
3 - objectionable
4 - very objectionable

The basins took from 6 to 12 days to reach the No. 1 level. The panelists noted that the odors did not carry very far beyond the basins.

The results of the tests were confirmed by Metro representatives during a field trip to drying basins in Sioux Falls, South Dakota; Topeka and Wichita, Kansas; and Tulsa and Oklahoma City, Oklahoma. None of those facilities had serious, continuing odor problems. However, odors were a problem where inadequate digestion occurred due to system failure (Reference 8).

The present Metro Denver operation at Lowry Bombing Range is monitored for odors and other factors by the Tri-County District Health Department. The Department also receives any complaints concerning odor problems of the operation. There are about 10 complaints a year concerning odors emanating from the site. These complaints come from areas up to 10 km [six miles] from the Lowry site. However, complaints coming from this distance were found by the Health Department to be unjustified ones: "The range of what were considered justified complaints was one or two miles [two to three km] from the Site" (Reference 39). The complaints usually conincided with unusual meteorological conditions and/or system failure.

Some past odor problems (such as the one occasioning the public hearing of 20 June 1972) were due to system inadequacies which were subsequently corrected. About 80 percent of the complaints were found by the Health Department to be due to other odor sources in the area, such as the landfill operation at Lowry and the gas processing plants in the vicinity. The remaining 20 percent of the complaints occurred during unfavorable weather or operation breakdown (Reference 39).

Anaerobically digested sludge will be less odorous than the material presently deposited at the Lowry site. After the sludge has been dried almost all of the volatile, odorous materials will have left the sludge. During normal operations, some odors will nevertheless be noticeable near the drying beds. During digester malfunctions (souring), severe odor problems may be expected if sludge is pumped to the site. If this occurs, the malodorous sludge will be injected at the site at agronomic rates.

Noise

Traffic, aircraft and farm equipment comprise the main sources of existing background noise in the vicinity of the proposed drying and distribution center, with an average noise level of 35 decibels on the A scale (35 dB-A) and a maximum of 60 dB-A (Reference 8). It is expected that the site will be designed in such a way that most of the noise-generating activities will occur at the center of the 800-hectare [2,000-acre] site and thus be surrounded by experimental fields. Further, it is possible to equip all internal combustion engines with noise mufflers, reducing noise to 80 dB-A at 15 m [50 ft].

Noise levels are expected to rise on Irondale Road with increasing truck traffic, particularly during the heaviest periods of sludge application. These noises, as well as all others discussed above, would occur only during the least noise-sensitive daylight hours and would not disturb the comfort of residences or pose a health threat to operators or other persons on the site.

Energy Use

Metro Denver Sewage Disposal District No. 1 used about 50 million kilowatt hours (KWH) of electricity for its total operations in 1975 (Reference 73). On a per capita basis, this amounts to about 50 KWH/person/year, which compares to a total per capita energy consumption in the United States of about 100,000 KWH/year (References 74,75). The current sludge handling and disposal system has total energy costs, for electrical power and fuel, equivalent to roughly 20 million KWH of energy (References 8,55,70), or 20 KWH/person/year.

Viewing the energy required for sludge handling and disposal in the perspective of the total energy use within the District's service area, sludge accounts for about 0.02 percent of the total energy consumption in that region. Viewed in absolute terms, it is roughly equivalent to the total annual energy consumption of 70 homes.

Energy Value of Sludge Nutrients--

An energy parameter of significance is the amount of energy required to produce and ship fertilizer in the area. For production of the three macronutrients essential for fertilizers: nitrogen, phosphorus and potassium, costs to the consumer that are due to energy costs are estimated to be 50, 25 and 30 percent, respectively (Reference 76). Assuming that the nutrient elements are available in proportions of two nitrogen, one phosphorus and no potassium in Metro Denver sludge, the weighted average energy equivalent of the nutrient value of the sludge becomes 40 percent.

If recycling of nutrients in the sludge is successfully achieved, a saving will be realized that is equivalent to the energy requirement for mining, manufacture and transport of commercial chemical fertilizers which otherwise would have been needed. Assuming (a) a nutrient value benefit of $28/metric ton [$25/ton] for Metro Denver sludge (on the basis that nitrogen is the only nutrient of value, with five percent of the dry matter in the sludge worth $0.55/kg [$0.25/lb]); (b) design production of 97 metric tons [107 tons] of dry sludge per day; and (c) an energy factor of 40 percent of the total fertilizer cost, an energy equivalent of about $400,000/yr is obtained. At $0.02/KWH, this translates into energy savings of about 20 million KWH per year.

Energy Produced in the Digestion Process--

Methane gas is generated in the anaerobic digestion process at the rate of nearly one cu m/kg [15 cu ft/lb] of volatile materials destroyed in the digestors. The energy value of methane thus produced will be almost 70 million KWH/yr using conservative assumptions in basic production rates. Since an equivalent of about 20 million KWH will be used annually for heating the digestors, a net gain of about 50 million KWH/yr would be realized if energy-conversion equipment (boilers, steam turbines, etc.) were to be available for utilization of the excess energy. At this point, however, such equipment is not envisaged in the facilities plan; therefore, this rather large energy item is not included in the total energy picture.

Energy Used in Transport of Sludge--

Another major energy economy can be achieved through the more efficient transportation system (in comparison to the Lowry disposal operations) designed for the recycling project. About 680,000 liters [180,000 gallons] of diesel fuel per year are consumed in the Lowry operation, assuming 35 truck trips/day, 80-km [50-mile] round trip and 1.5 km/l [3.5 miles/gal] (References 55,77). This energy is equivalent to nine million KWH/yr and is included in the total energy figure given above for the present operation of the sludge handling and distribution systems.

By contrast, only about 80,000 liters [20,000 gallons] of fuel per year would be required to deliver the present sludge load to the land application areas. Net savings accomplished by the new transport system (including the sludge pumping energy requirement) over the Lowry operation amount to about eight million KWH/yr.

Energy Balance in Sludge Transport to Farms--In order for the shipping of sludge, from the drying and distribution center to reuse areas, to be economical, the cost of shipping must not exceed the price of equivalent fertilizer delivered at the reuse site. This assumes no value for the soil-structure-enhancing benefits of sludge recycled to land. Assuming further that nitrogen is the only constituent of value in sludge, maximum distance--beyond which shipment of sludge would be uneconomical--is obtained by:

$$D = \frac{F \cdot N \cdot W \cdot S}{Y} \qquad \text{(Equation 3)}$$

in which: D = distance from the distribution center to the ultimate application area,

F = fertilizer cost,

N = fraction of nitrogen in the sludge dry solids,

W = fraction of total solids in the sludge shipped,

S = specific weight of stockpiled sludge, and

Y = volumetric unit transport cost.

With: F at $0.55/kg [$0.25/lb] of elemental nitrogen,

N at 0.05, i.e., five percent of the dry matter,

W at 0.50, i.e., 50 percent of the sludge,

S at 560 kg/cu m [35 lb/cu ft], and

Y at $0.08/cu m-km [$0.10/cu yd-mile],

the breakeven distance, D, is calculated to be nearly 100 km [60 miles].

In summary, it can be seen from the discussions presented above that a total energy saving of at least 28 million KWH/year could be realized if a successful sludge recycling program were instituted to replace the present system: eight million through abandonment of the Lowry operation and 20 million from fertilizer recycling revenues. This is equivalent to the average annual energy consumption of 98 homes, or about 0.03 percent of the total energy consumed within the District boundaries in a year.

Aesthetics

The visual impact of the proposed sludge drying site, as designed, will be perceptible mainly from within the site and from above (from aircraft). The demonstration plots will be visible to the passing motorist from Irondale Road, the most heavily travelled road bounding the site (though even this road carries only about 210 vehicles per day). The beds are, however, about 400 m [1300 ft] from Irondale Road and generally slope away from the road so they will be relatively unobtrusive. It is expected that thae site of the drying basins may be unpleasant to those associating the site with the fecal origin of sludge. Otherwise, the distinctive geometric patterns formed by the basins (schematically presented on Figure 13) and stockpile windrows could provide an interesting visual contrast (particularly from the air) to adjacent farmland patterns. The association of the project with energy and resource conservation will further improve its aesthetic status in the minds of people who are aware of the limits of our planet.

Plant Operation and Plant Effluent Quality

Because Metro is installing anaerobic digesters at the Metro Central Plant, a different strength waste stream will result compared to the present system. In a wastewater treatment plant using digesters, supernatant from the digesters is often recycled to the plant. This recycle stream can put an additional treatment burden on the plant operation from addition of suspended solids, BOD, ammonia and other substances.

With the Metro land recycling proposal, the digester supernatant would be pumped along with the digested sludge to the drying and distribution site. This proposal would therefore leave the recycle situation at the Metro plant comparable to what it is now. However, if the use of the Lowry Bombing Range were continued for disposal (and presuming that the present operation of vacuum filter and truck haul were also to be continued with digested sludges) the Metro Central Plant would experience additional loads on the liquid treatment portion of the plant. A rough estimate of the additional load would be as follows: suspended solids: 10 to 15 percent, BOD: 3 to 6 percent, and ammonia: 4 to 8 percent, assuming both Metro and the Northside plants were to recycle or add supernatant to the plant. The first two constituents would probably be further treated in the plant process and might not affect effluent quality. Ammonia, however, could pass through existing plant treatment units unchanged and increase ammonia loadings to the South Platte River. Any alternative involving recycled supernatant to the wastewater plant would have this effect.

The tradeoff between the Metro proposal and any alternatives involving recycle to the plant involves the additional treatment that may be necessary at the drying site to handle the supernatant and additional excess water in the digested sludge. Cost estimates for various control methods which may be used to prevent migration of soluble nitrate in the sludge water into the groundwater are presented in Volume II, Issue IV-2.

Natural Resources

While the proposed action will conserve a presently wasted resource of significant potential value, it will require use of fuel for transport and application of sludge to land and will necessitate disturbance of the soil resource on some 240 hectares [600 acres] of the proposed drying basins and stockpile areas.

Organic Matter and Plant Nutrients

The single most important impact of the proposed action is the conservation of the soil-conditioning/fertilizing capability of sludge. Within the framework of limitations discussed in Section IV, sludge comprises a valuable resource whose magnitude is only now becoming apparent to the general public. Depending on process train and application type, the total nitrogen value alone of Denver sludge can range from $4 to $4.6 million per year under present prices and values. Sludge contains phosphorus in abundant quantities as well as minor amounts of all other essential elements. It also has the ability to improve soil conditions for plant growth. However, it lacks adequate potassium. It is expected that the money-equivalent value of sludge will increase sharply in future years as fossil fuels (primary sources of commercial nitrogen fertilizers) become ever more scarce and other shortages of natural resources become more apparent than at present.

Use of Fuel for Transport of Sludge--

As discussed above under Energy Use, the fuel required under the proposed action is far less than that used for present operations at the Lowry Bombing Range site. Nevertheless, it is a significant commitment of resources.

Soil--

Disturbance of soil profiles at the sludge drying basins has already been discussed in the early part of this Section, under Soil Loss, and need not be restated here.

Archaeology and History

The proposed project should not have an adverse impact on either the archaeologic or the historic characteristics of land affected by the proposed project. Land underlying the site of the anaerobic digestors has already been developed, as has the land adjacent to the proposed pipeline route. Furthermore, there was no superficial evidence at the proposed drying basin site to indicate underlying archaeologic sites (Reference 8), and no historic sites have been designated in that area (Reference 43).

While all evidence indicates that the proposed project will not jeopardize archaeologically or historically important sites, the remote possibility exists that heretofore unknown sites will be discovered during construction activities connected with excavation of areas for the installation of anaerobic digestors, with laying the pipeline and with construction of the drying basins. In the event of such a discovery, the Colorado State Antiquities Law should be reviewed and its provisions implemented. The particular significance of this law in relation to the National

Historic Preservation Act of 1966 and the Archaeological and Historic Preservation Act of 1974 should be recognized in making provision for the possible discovery of archaeological and historic resources. More discussion of archaeological issues is found under Issue I-4.

Land Use

Land uses within the immediate boundaries of sites to be used for the installation of the anaerobic digestors, pipeline route and drying basins will change as a result of implementation of the proposed project. These changes will be compatible with surrounding land use activities and will not conflict with relevant land use plans or zoning regulations.

Installation of anaerobic digestors at the Metro Denver Central Plant facility will cause an internal land use change. This change will be compatible with the present use since plant operation will not change and use of the land will continue to be for sewage processing.

The proposed pipeline route, lying beneath the roadway right-of-way areas, will not precipitate adjacent land use changes. Except for other utility and municipal service lines which lie beneath these areas, the land is presently vacant; addition of the pipeline will leave the status of the land unchanged.

The agricultural area to accommodate the sludge drying and distribution site will change in use, but this change will be compatible with surrounding land uses since the project will provide fertilizer for agricultural use. Because of this function, the proposed location of these basins is consistent with Adams County land use plans and with County zoning regulations which seek to perpetuate both agricultural and agriculture-related land uses (References 45,46). A potential impact of benefit would result from reduction of pressure for future large-lot subdivision in the vicinity of the sludge drying and distribution center.

It is not likely that the proposed storage and distribution system will provide the stimulus for any significant land use changes in the surrounding area. At this time it appears that the major cause of future land use changes in the area will be the proposed Adams County General Aviation Airport. Sites to the west of the proposed sludge drying and distribution center are being considered for the airport. A "growth corridor" running from the proposed airport northwest to Brighton is likely. The drying and distribution center might limit growth which would otherwise extend eastward from the proposed airport. However, in general there appear to be no major negative land use impacts associated with the proposed drying and distribution center (Reference 44). Further discussion of this topic is found in Volume II, Issues II-4, II-9 and II-10.

Land Tenure

Should the proposed project be implemented, there will be varying effects on land associated with the sludge processing, transfer and drying facilities. In terms of the Metro Denver Central Plant, there will be no impact on land tenure since no transfer of ownership is anticipated. Likewise, no tenure change is anticipated for the roadway right-of-way areas for the pipeline since an easement will probably be obtained. However, ownership of the drying basin site will be transferred from private into public ownership.

No other impacts on land tenure will be incurred by the proposed project. The Lowry Bombing Range and landfill site will remain in public ownership whether or not the project is implemented.

Population

The project will not have a significant impact on the population growth rate in Adams County or in the Metro Denver service area as a whole. It seems likely that the project would encourage the continuation of agricultural activity and sparse population in the region surrounding the drying site. This impact on population distribution is predicated on two factors: (1) The proposed project would provide a conveniently located source of fertilizer/soil conditioner, to the benefit of farmers; and (2) the project may inhibit residential development in the immediate vicinity of the sludge drying site.

The impact on population distribution is uncertain and will probably be diffuse. It would tend to maintain a sparsely populated rural area in its present state and thus aid in limiting sprawl radiating from the Denver area.

The 18 new jobs generated by the drying/distribution center will not significantly affect population growth or distribution in the area. It is expected that the project will have no significant growth-inducing impacts.

Transportation and Circulation

The proposed project could have a variety of direct impacts on transportation facilities which will serve the proposed drying basin site. Average daily traffic (ADT) will increase, roadways will deteriorate, highways might become littered and dust will be generated as a consequence of sludge trucking. No impacts are expected on transportation facilities located in the area surrounding the Metro Denver Plant or along the proposed pipeline route.

Average Daily Travel--

Average daily travel will increase on roadways serving the proposed sludge drying and distribution center as a result of trips made by facility employees traveling to and from work and trucks using various roadways to deliver dried sludge. The majority of this traffic will be concentrated on such roadways as Irondale Road, Bromley Lane and Hacksmount Road, which will serve the drying and distribution center. The impact declines as roadway travel radiates toward destination points. This increase in average daily travel will not adversely affect traffic flow since the roads in question are infrequently traveled and have design capacities adequate to carry the additional traffic.

Assuming an average daily sludge production of 190 metric tons [210 tons] and a truck capacity of 14 metric tons [15 tons], annual truck traffic will total about 5,000 trips. Assuming a delivery period of four months (two months during the spring and two months during the fall), five days per week, daily truck trips will total 60 to 65. Further assuming a delivery radius of 100 km [60 miles] from the sludge drying site, this number of truck trips distributed over an area of over 31,000 sq km [11,000 sq miles] will not cause a significant impact on traffic.

Highway Bridge Capacity--

A potential problem is inherent in the fact that highway bridges in some areas have posted capacity limits below 14 metric tons [15 tons], the assumed average truck load. County Road 30, for example, which serves the representative irrigated farm in Weld County, includes two bridges, 30/25A and 30/25B, the former with a posted limit of 4.5 metric tons [five tons] and the latter with a capacity of seven metric tons [eight tons] (Reference 105). The routing of trucks will therefore require consideration of bridge capacities in order to avoid accidents and bridge damage.

Traffic Dust--

Unpaved sections of roadway, on Weld County Road 30, for example, can lead to dust problems under conditions of heavy traffic. Because many areas in which deliveries will occur are under the jurisdiction of an air pollution control district, Colorado's Fugitive Dust Law will apply, requiring a dust abatement plan to be filed prior to the start of deliveries over unpaved roads (Reference 104).

Dust generated by increased traffic could annoy residents of the area. This problem would be minor, however, since most of the roadways are paved except for a six-km [four-mile] segment of Hacksmount Road (Reference 103).

Damage to Roadways--

It is expected that deterioration of road conditions will accelerate as a consequence of increased average daily traffic associated with the conveyance of three-axle trucks carrying dried sludge loads estimated at 14 metric tons [15 tons] (Reference 77). Hacksmount Road, Bromely Lane and Irondale Road have design capacities adequate for such loads and presently are used by agriculture-related trucks carrying similar loads.

Sludge Spillage in Transit--

Load spillage on these roadways is another potential problem related to the distribution operation. However, spillage occurring on roadways related to the Lowry Bombing Range facilities, whose operation is similar to that of the proposed delivery system, has been minor, with only two sludge-carrying trucks having overturned during three years of operation (Reference 77). Therefore, it can be assumed that spillage and littering will not be a major problem in the operation of the proposed project.

Recreation

Odors produced by operation of the proposed project represent the only potential impact of the project on recreational areas and their users. Impact would be limited to the vicinity of the Metro Denver Plant, which will house anaerobic digesters. Should those digesters fail, odors produced would radiate for a distance of 1.5 to 3 km [one to two miles] from the Central Plant facilities. The only recreational area located within that distance is a ten-mile segment of the South Platte River area proposed for boating, bicycling and picnicking activities (Reference 106). Although some users would be affected by odors once the recreational area had been developed, the impact would not be a major one. Overall plant odors are more likely to be the chronic nuisance.

The probability of anaerobic digester breakdown is small; design features appear to be adequate, and operational precautions will presumably be incorporated. If a system failure does occur, the impact period will be limited to the time required for repair. The potential impact of such a failure is considered minimal because the Metro Denver facilities are located in an industrial corridor. Other odors generated in this area would tend to mingle with and hence lessen the perceptible intensity of those produced by anaerobic digester failure. There are no recreational areas within the odor range of the pipeline facilities or drying basin areas.

Governmental Agency Jurisdiction

The proposed project has precipitated a jurisdictional dispute between Adams County and Metro Denver. The relative authority of these two bodies over the proposed project has become the subject of litigation. The proposed project would remove the Metro Denver sludge management operations from the Lowry Bombing Range and therefore from the jurisdiction of the City and County of Denver. While the present working arrangement has been satisfactory, the District could not expand beyond the present disposal area.

The project does not appear to be in conflict with any activities of planning agencies concerned, with regard to jurisdiction in the study area. However, an important question remains as to which agency will have the necessary authority, responsibility, funding (for monitoring, surveillance and enforcement of proper application restrictions) and administrative structure to regulate the proposed project.

Employment

A full-time staff of 18 people will be required for operation of the distribution center facilities at full development (1985). This will not have a significant effect on employment in the area.

Land Values

If the proposed drying and distribution center is operated according to accepted sanitary engineering principles, it is not expected to have a significant ultimate effect on surrounding land values (References 66,52).

Some impact, over and above the various physical impacts described elsewhere in this report, would probably be felt on the value of land surrounding the proposed project. A psychological impact, which would make people reluctant to live near such a center, would inhibit residential development around the site. This could limit future increases in property values associated with such development. On the other hand, agricultural activity might be intensified in the proximity of the fertilizer storage and distribution system, and secondary development associated with such increased activity might also occur. Each of these events would be likely to raise property values.

While it is difficult to generalize from other sludge recycling operations, land values near other such projects have not decreased and it is therefore considered unlikely that decreases would occur in the vicinity of this operation (Reference 108).

Therefore, the net effect of the proposed project on the value of property surrounding the site is likely to be minor (see Volume II, Issue II-4).

Construction Impacts

Transportation and Circulation--

Transportation facilities associated with the Metro Denver Central Plant facility, the proposed pipeline route and the drying basin site may be affected during the construction phase of the proposed project. However, these impacts will be of short-term duration and in most cases insignificant.

In order to construct anaerobic digesters, large equipment will be moved in over roadways surrounding the Central Plant facility. This activity may cause a disruption of normal traffic flow patterns and may even necessitate traffic diversion. However, such impacts will be of a temporary nature and will be insignificant since the transport of heavy equipment into the industrialized corridor surrounding the plant is a normal occurrence.

Pipeline construction activities may be of longer duration than those associated with the digester construction. Traffic patterns on adjacent travelways such as Irondale Road and Colorado State Highway 2 could be affected. Construction impacts associated with Irondale Road should not be a problem since activity will concentrate on right-of-way areas and should disrupt traffic on this infrequently traveled rural roadway to only a minor extent. Construction activities adjacent to 104th Street may have a more severe impact because this travelway accommodates large volumes of daily traffic. Impacts incurred, including delay periods and possible detours, will be temporary.

Activities of 80 to 100 construction employees, deliveries, inspections, etc. associated with construction at the drying basins will increase average daily traffic on servicing roadways by 360 (Reference 55). These roadways have the capacity to accommodate the temporary increase. Because current average daily traffic on these travelways is low, temporary slowing of traffic over them will not be significant. Therefore, any impact incurred will be negligible.

No other construction-related impacts on transportation or circulation are anticipated as a result of the proposed project.

Flora and Fauna/Habitats--

The temporary nature of the construction activities at the Central Plant, along the pipeline and at the drying/distribution site tends to minimize impacts upon flora, fauna and wildlife habitats. With successful quick revegetation and adequate planning, construction impacts can be kept below significant thresholds.

Soils--

Soil profile along pipeline route will be completely destroyed and replaced by a blending of underlying materials and the initial soil layers. The linear nature of this impact makes it of relatively little concern, especially since most of it will take place along the previously disturbed soils of road easements.

Utilities--

In order to extend electricity and telephone service to the drying basin site, easements will be obtained along farmlands and roadway right-of-way areas (Reference 72). During construction activities, farming operations and even travel on adjacent roadways may be disrupted. However, the impact would be of short duration and the area of disruption small in scale.

Air Quality--

During construction of the drying and distribution facility and the pipeline, dust will be generated and pollutants emitted by construction equipment. However, the effect on ambient air quality will be insignificant. While much dust will be stirred up on the project site, this impact will be temporary and will be localized to a very sparsely populated area.

Employment--

During construction of the pipeline and distribution center, 80 to 100 people will be employed. These workers will be recruited from the local Denver area work force.

Secondary Impacts

Economy--

The construction of a large public facility inevitably has impact on the local economy as a result of both the construction process and the subsequent operation of the facility.

Direct economic impacts, including employment and potential impacts on agricultural activity, are discussed elsewhere in this volume, both with regard to temporary construction employment and to permanent employment. With respect to the operation of the facility, there appear to be virtually no significant secondary impacts other than those associated with agricultural activity. The small volume of permanent employment and the relatively small demand on community resources--when the facility is fully operational--suggest that secondary impacts of the operation will be negligible or nonexistent.

The same conclusions cannot be drawn with respect to secondary impacts of construction. The total capital cost of the proposed facility is approximately $17.8 million. The maximum construction employment will be approximately 130 persons. In addition, a substantial portion of the capital cost will be accounted for by items other than direct labor, with a fraction of this amount expended for local materials and services.

Two steps are used for estimating secondary impacts. First, an attempt is made to make preliminary allocation of capital costs among labor and materials and to provide an estimate of the allocation of the material costs between local and imported components. The second step uses an employment multiplier dealing exclusively with construction employment to estimate the potential indirect employment that will be created.

The estimates are based largely on experience with other, similarly capital-intensive projects in Devner and elsewhere, using the lower end of estimates to formulate possible minimum dollar impact on the local economy. The results of the initial step are shown on Table 21.

It is assumed that only half of the "materials, expenses, fees, etc." component will be spent in the Denver Standard Metropolitan Statistical Area. This assumption is not as completely conservative as it may seem; while many of the materials and services may be purchased in the Denver metropolitan area, their original sources lie elsewhere, and the value added in distribution within the local metropolitan area may be relatively small.

Employment--

The foregoing analysis suggests that approximately $5.2 million in total payrolls may be generated locally by the project along with approximately $9.35 million in local expenditures for material expenses, professional services, etc.

Table 21. ESTIMATED CAPITAL COST AND APPROXIMATE ALLOCATION TO LAND, LABOR AND MATERIALS

Cost estimate and allocation	Amount, 1974 $
Capital cost (not including digesters)	17,800,000
Less estimated land cost (800 ha @ $625/ha)[a]	500,000
Total cost of improvements	17,300,000
(including contingencies, processing costs and engineering and other professional costs)	
Approximate allocation	
Direct labor (20 percent)	3,460,000
Indirect labor (5 percent)	865,000
Materials, expenses, fees, etc. (75 percent)	12,975,000
Spent in Denver SMSA[b]: $6,488,000	
Imported: $6,488,000	

[a] [2,000 ac @ $250/ac].

[b] Denver Standard Metropolitan Statistical Area.

These estimates of expenditures may in turn be subjected to further analysis to develop estimates of indirect employment and economic impacts on the local economy. The purpose of this exercise is to determine the order of magnitude of such impacts. Quantification on any more precise basis would require disaggregation of capital cost, which is not now available.

As suggested above, gross payrolls associated with construction of the project are approximately $5.25 million. It is a reasonable inference that approximately 70 percent would be directly reflected in the local retail purchases. This would amount to approximately $3.7 million, an amount well under one percent of the retail sales in Adams County.

Based on an approximate up-date of the 1972 Census of Business estimates, the retail sales per employee are approximately $52,000. Thus, the introduced $3.7 million would create the annual equivalent of approximately 70 additional person-years of new employment.

The nonlabor expenditures associated with the capital cost of the project would be spread over a wide range of materials and services, probably concentrating in the building and construction materials and transport services areas. A tentative approximation of sales per employee in these sectors suggests that they are perhaps $60,000 to $70,000 per employee. On that basis, the employment impact of these materials and other expenditures would be approximately 140 employees.

On the basis of preliminary and rough analysis, it is possible that the aggregate impact of construction of the project would be 210 person-years of employment. Since the additional employment impact will spread over the entire Metropolitan Denver area, the relative impacts will be fairly trivial, amounting to less than 1/20th of one percent of the areawide employment.

Other Secondary Impacts--

Infrastructure investments discussed above can have serious negative secondary impacts on air quality, urban runoff, sensitive areas, etc. from population growth induced or accomodated by the proposed project. The sludge processing and disposal project is necessary for the efficient operation of the overall Metro wastewater system. Furthermore, the issue of secondary impacts is being analyzed in detail in the EIS on Metropolitan Denver Facilities Plans. Therefore, discussion of secondary impacts are deferred to that EIS process. It is apparent that control over population growth patterns can be more directly effected through the individual wastewater facilities plans and NPDES permits.

Impacts of Sludge Disposal at the Drying and Distribution Center--

Because the disposal portion of the operations at the processing site involves land application of sludge, the discussion of its impacts is presented on page 166 after the discussion of recycling impacts and prior to disposal impacts.

Summary of Impacts at the Sludge Drying and Distribution Center

The most serious negative environmental impacts at the sludge drying and distribution center are on soil properties, groundwater quality and the public health through nitrate pollution of groundwater and pathogen problems. Positive impacts are energy and resource conservation. The impacts are schematically represented on Figure 16 in a summary format to indicate the rough order of importance EPA places on the various impacts surrounding the drying/processing operation.

FIGURE 16

SUMMARY OF POTENTIAL IMPACTS AT THE PROPOSED SLUDGE DRYING AND DISTRIBUTION CENTER FOR METRO DENVER

Impact parameter	Direction and potential intensity[a]
Soil loss/farmland productivity	⬤
Groundwater quality	⬤
Surface water quality	•
Water rights	•
Public health--Pathogens	●
Public health--Nitrates	⬤
Public health--Vectors	•
Loss of habitat	•
Air quality (including odors)	•
Energy use	◯
Natural resources	◯
Construction impacts (overall)	•
Secondary impacts (economy/employment)	∘

[a] Symbols signify relative impacts, as defined below:

	High	Moderate	Low
Positive (beneficial) impacts:	◯	○	∘
Negative (adverse) impacts:	⬤	●	•

This schematic representation of impacts should only be interpreted within the context of analyses of impacts presented in the main body of the EIS. It is neither an attempt at quantifying the impacts nor reducing the diverse environmental parameters to common bases for comparison. However, it does provide a rough ranking of the relative importance of the various impacts. The scales denoted by symbols used above are not intended to be compared with those used on Figures 17 and 18. These impacts are also subject to mitigation which could lessen their importance.

IMPACTS OF LAND APPLICATION OF SLUDGE ON THE RECYCLING AREAS

General

A large body of new data is being developed in various parts of the country on impacts of sludge reuse in agricultural and related activities under a wide variety of conditions. A single salient conclusion of the collective evidence to date is that the impacts are site-specific. Thus, statements made in the following paragraphs are necessarily applicable to the types of sites which are described in Section III and Appendix E under Environmental Setting. Even though a finite number of sites were investigated for the purpose of impact analysis, it is recognized that dried anaerobically digested sludge may be used for a rather large variety of applications. It is expected that the city parks, sod farms, mine spoil sites, irrigated and dry farms and home gardens will provide examples of the entire range of application site possibilities and provide the information necessary to evaluate the advisability of using the material on proposed sites.

As an introduction to impacts of sludge application on land recycling areas, a graphic representation of the severity of the various impact parameters on the representative types of application sites is presented in Figure 17. All of the subjective impact levels assigned can be qualified depending upon prevailing conditions, management practices and other mitigating circumstances. These qualifications are presented below with particular emphasis on site specificity. An overview of the major concerns and advantages of each type of land application site is presented prior to the presentation of the impact parameters.

City Parks--

The application of sludge to city parks is potentially problematic because of the high rate of public use of the parks for recreation. Although sludge has been, and is being used, as fertilizer on the parks in the past, publicity resulting from the large scale of the proposed project may engender some concern, if not opposition. Public involvement is important, and the Denver Department of Parks and Recreation should promote a program of public awareness to inform the public as fully as possible of the benefits and potential effects of sludge application. Additionally, the use of sludge on the City parks should be rigorously monitored to ensure the success of the program. The viability of pathogens (especially *Ascaris* ova) is perhaps the most crucial issue and should be closely monitored. The use of additional methods for pathogen reduction, as described in detail in Section VI and Appendix D, would provide additional protection to the public.

FIGURE 17

SUMMARY COMPARISON OF RELATIVE POTENTIAL IMPACTS[a] OF SLUDGE RECYCLING ON VARIOUS LAND APPLICATION SITES IN THE VICINITY OF DENVER

Impact parameter	Sludge application site						
						Home gardens	
	City parks	Sod farms	Mine spoil sites	Irrigated farms	Dry farms	Ornamentals	Edible plants
Food chain	•	·	·	●	•	•	⬤
Public health	•	·	·	•	•	●	⬤
Water quality	•	•	•	•	·	•	•
Soil productivity	◯	○	○	◯	◦	◯	◯
Soil salinity	•	•	·	•	●	•	•
Soil heavy metals	•	•	·	●	•	•	●
Air quality	•	•	•	•	•	•	•
Vegetation	◯	◯	◯	◯	◯	◯	◯
Wildlife	•	·	○	•	•	•	•
Habitats	·	·	◯	·	·	·	·
Odor	•	•	·	•	·	•	•
Noise	•	·	·	·	·	·	·
Aesthetics	•	·	◯	·	·	·	●
Natural resources	○	◯	◯	◯	◯	○	○
Traffic and circulation	•	·	•	·	·	·	·

[a]Symbols signify relative magnitude and direction of impacts, as defined below:

	High	Moderate	Low	None
Positive (beneficial) impacts:	◯	○	◦	·
Negative (adverse) impacts:	⬤	●	•	·

This schematic representation of impacts should only be interpreted within the context of analyses of impacts presented in the main body of the EIS. It is neither an attempt at quantifying the impacts nor reducing the diverse environmental parameters to common bases for comparison. However, it does provide a rough ranking of the relative importance of the various impacts and a comparison of sites vis-a-vis each parameter.

Sod Farms--

The sod farms of the Denver area represent a specialized type of irrigated farm. While impacts are evaluated specifically for one specific sod farm, many of the impacts may be extended to operations in similar situations. Generally, sod farms represent the best type of land recycling sites for sludge from the environmental viewpoint. The applied sludge and its constituents are transported away from the sites and distributed thinly over a very wide area.

Mine Spoil Sites--

The proposed mine spoil sites for sludge application are heavily disturbed unnatural areas. The proposed action represents an initial step towards reclamation of these "waste areas" and, thus, all impacts are evaluated in this perspective. No food crops are assumed to be grown on such spoil sites. Public access and exposure to the sites, especially during the reclamation period, will be limited. Thus, mine spoil sites are generally the least problematic for sludge reuse purposes.

Irrigated Farms--

Irrigated farms represent the type of land application candidate sites which may become major users of the Metro sewage sludge. Allowable annual application rates are fairly high, as shown in Figures 14 and 15 in Section IV. Consequently, the number of years of safe application is relatively short. Thus, the opportunity for corrective action, if indicated, is more limited than in the non-irrigated applications. On the other hand, irrigated farms are generally more intensively and carefully managed because of the higher value of crops grown on these farms. In fact, many irrigated farms have highly sophisticated irrigation equipment capable of automatic control with sensors connected to tensiometers and other devices determining plant-soil moisture status.

The availability of a competent and well-equipped management system tends to give better assurance of (a) proper control of application rates, (b) careful monitoring of soil, crop and water quality responses to applications of sludge to land and (c) accurate recording and mapping of areas receiving measured quantities of sludges from the very first application until the limit is reached, and beyond.

Application of lime, supplemental phosphorus and potassium, if needed, and irrigation water are common practices on these farms and can be readily adjusted to meet the additional requirements imposed by the sludge application.

Therefore, while irrigated farms will be potentially the most extensively and intensively affected by the sludge reuse scheme, they are also the areas that offer the greatest opportunity for control and mitigation.

Non-Irrigated Farms--

Non-irrigated farms abound in Weld, Adams and Arapahoe Counties, surrounded by extensive areas of drylands used as non-cultivated pasture. These areas generally have very low fertility, as shown by production rates per unit surface area, reported by the Colorado Department of Agriculture (Reference 95 and shown on Table E3 in Appendix E). The low fertility is in part due to continuous cropping with little fertilization or amendment. It is not expected that dry farms will also become extensive users of the Denver sludge at low surface application rates over large areas and over a much prolonged period of time.

Use of liquid sludge will probably be more successful on drylands and non-irrigated farms with subsurface injection tools than use of the air-dried material. This is because the injectors can serve the double function of soil water conservation through scarring the land surface while applying sludge at a safe depth below the soil surface.

In general, impacts of sludge application on non-irrigated farms and drylands will be far less intensive than the other agricultural reuse candidate sites discussed in this volume. Furthermore, the low application rates provide a safety mechanism and greater opportunities for corrective action should unforeseen negative impacts become evident in the future. The low application rates could prove uneconomical to dryland farms.

Home Gardens--

A significant number of gardeners, organic growers and others raising crops on relatively small scales have expressed interest in and enthusiasm for the use of anaerobically digested dried sludge for application to their soils (see Appendix F). Due to the potentially large numbers and wide separation of sites in this type of use of the sludge, it could be very difficult for any jurisdiction to provide the supervision, control and monitoring that is essential to the success of (including prevention of environmental hazards from) sludge recycling on the land. Furthermore, the potential for direct human exposure to the material would be great because automated and mechanical application is impractical on small-scale operations. Some home gardeners would use the sludge for amending soils supporting ornamental plants; others would use it on edible crops. There are far fewer potential hazards associated with ornamental than edible (especially leafy vegetable) crops growing on soils amended with wastewater sludge. Regulating proper use of the sludge and maintaining public health protection in home gardens would require a very determined public education effort including clear labelling, instructions, warnings, spot checks and, perhaps, provision of legal constraints.

Food Chain

The impact of sludge application in irrigated farms and home gardens upon the food chain is largely dependent upon the types of food crops or feeds grown for direct and eventual human consumption. Leafy parts of vegetables, beets, mint, vine, lettuce and chard are examples of crops which accumulate cadmium in greater concentrations (sometimes up to ten times) than found in the soil. The animals eating such crops and ingesting sludge-amended soil will further accumulate cadmium in the kidneys, liver and some other organs and tissues. Eating these tissues could give rise to kidney diseases and hypertension in humans. Some people tend to consume these less expensive tissues as a substantial part of their diets. The irrigated crops grown in the area are mainly wheat, corn, barley, sorghum, beans, beets, oats, hay and potatoes. None of these crops is usually consumed unprocessed and/or raw and none is known to be a particularly heavy accumulator of metal elements in their usually edible parts. On the other hand, leafy vegetables grown in home gardens such as Swiss chard, spinach and lettuce tend to magnify cadmium concentrations in their edible tissues.

Because of its high toxicity, cadmium is the most important element of concern in the Denver situation, while copper and zinc are far less important due to very low concentrations and much lower toxicities.No standards have yet been established for the limitation of cadmium in foods. The U.S. Food and Drug Administration proposes to establish such standards for cadmium in the near future. Generally, as long as sludge cadmium content is below one percent of the zinc concentration, and as long as recommended application rates are not exceeded, potential cadmium toxicity in the food chain will be minimized. Recent analyses (Table D-4 in Appendix D) indicate that even though cadmium levels are far below average for municipal sludges, average cadmium in the Denver sludge is about 1.7 percent of the zinc content. Although this value somewhat exceeds the one percent limit stated above, existing mitigating circumstances are expected to adequately compensate for this ratio. The favorable circumstances are (1) highly calcareous conditions, particularly in the lower soil horizons on most of the irrigated farms; (2) the conservative nature of the ultimate sludge loading rate, given in earlier sections; (3) the relatively high phosphorus content of Denver sludge, which tends to help make both zinc and cadmium less available to plant species;

and (4) the poorly defined concept of "reversion," in which heavy metal elements gradually become combined into stable, unavailable compounds. This latter process is most rapid in calcareous, alkaline soils such as encountered in most of the study area. Possible lowering of pH during the first few years after sludge application may lead to release and uptake of these elements.

Another important consideration is the possibility of reduction of the quantities of heavy metals in the wastewater system from industrial and other sources in the future years. It is probable that significant reduction will be accomplished before the ultimate surface application limit is reached on most irrigated farms.

The other elements of major concern to the food chain, including copper, zinc, molybdenum, selenium and lead, are of sufficiently low concentration in the Denver sludge so that they are not expected to produce an adverse impact upon the food chain. The favorable soil conditions discussed above also protect against most other metals. Most toxic metals sharply reduce crop yields before they become high enough in concentration to pose a food chain hazard. This phenomenon constitutes a safety valve in the food chain. Additionally, organic compounds in sludge are able to chelate heavy metals, making them even less available.

Crops grown on non-irrigated farms are primarily winter wheat and barley with lesser areas of grain, corn, sorghum, oats and spring wheat. From the point of view of preventing heavy metals accumulation in the food chain, more suitable cropping patterns would be hard to accomplish. The parts of these plants which are used for animal feed and/or processed for human consumption are not known to be accumulators of cadmium or any other heavy metals. It is not expected that cropping patterns will change appreciably in the future years; hence, it is expected that no significant food chain hazards will exist with sludge reuse on non-irrigated farms.

Sludge application, in excessive amounts on rangeland may result in accumulation of cadmium and other heavy metals in the leafy parts of some weeds. Domestic animals feeding on these rangelands will in time accumulate these elements in their tissues and pass them along to humans who eat the meat (especially liver and kidneys) thus produced. As long as recommended application rates are not exceeded, excessive accumulations are not expected to occur. However, direct ingestion of sludge-amended soils by livestock (ten percent of whose diet is soil particles) can significantly increase heavy metal magnification along the food chain. The present operations at the Lowry Bombing Range are most conducive to this sort of heavy metals assimilation by grazing animals.

The most effective and long-lasting solution to heavy metal magnification problems in the food chain is removal--or reduction--of discharges containing toxic elements from the sewer system, as mentioned above. This can be achieved through an extensive program of source identification, promulgation of standards, regulation and intensive enforcement of the discharge quality standards on industrial dischargers. This topic is discussed further in Volume II, Issues I-1 and V-1.

Public Health

Although no documented cases exist in the United States that associate the use of digested sludge on land with human disease, two major factors require that the possibility of such an occurrence be considered. First, City parks are heavily utilized by the public who may come in contact with sludge in a number of accidental and unforeseen ways. Secondly, although sludge processing destroys a significant number of pathogens, some may survive over long periods of time (see Table 20 on page 114). The use of sludge on City parks is practiced in many parts of the country with no reported public health problems.

Pathogens--

The greatest areas of concern are home gardens where the possibility of direct human contact with pathogens on the soil, ornamental plants and edible crops is quite high. The long survival time observed for viruses and *Ascaris* ova makes it imperative that (1) no food crops be raised on sludge-amended soil to be eaten directly (unprocessed, raw) by humans, (2) long field re-entry periods be established and strongly enforced on areas where sludge is applied, (3) cases of disease contracted from sludge sources be identified, documented and followed through and (4) a very rigorous public health monitoring program be established as an integral part of the reuse of sludge on food crops of all types.

The pathogen problems associated with the dried sludge delivered to sludge recycling sites will be somewhat less intensive than the material at the drying and distribution center because of the natural die-off of the pathogens with time. However, the greater possibilities for human contact bring up additional possible public health impacts. If sludge is used to fertilize crops or home garden vegetables which will be eaten raw within the first year of application, adverse health impacts could well result. If the one-year wait is observed, no significant health impact is expected. Recommended waiting periods of from one year (Reference 81) to three years (Reference 79) between sludge application and growing of crops to be eaten raw have been suggested. However, Metro plans presently call for a one-year drying period in the drying basins only, before release of sludge to the consumer.

The EPA preliminary proposed wait of three years before raising crops to be eaten raw (Reference 79) is a cautious waiting period for a cool, dry region like the Metropolitan Denver area. Table 20 indicates that *Ascaris* ova are the limiting factor in setting a safe period for pathogen die-off. The EPA document is nation-wide in scope, however, and the *Ascaris* problem is primarily of concern in moist tropical regions, such as some southern states (Reference 111).

Ascaris is not of great enough importance in Colorado to be listed among the 22 diseases on the Colorado State communicable disease report; the disease ordinarily has mild--often almost unnoticeable--symptoms. This disease has a very low incidence in the area, and the long survival time for the parasite's eggs, applies only under conditions favorable to the roundworm. The arid, cold seasons common to this area do not provide this environment.

The next hardiest pathogens are tubercle bacilli, which can survive only six months. Continued application of sludge to parklands will have no significant adverse health impacts. The anaerobically digested sludge will have fewer pathogens than the material presently being applied to the parks. If a two-year drying period is instituted, it will ensure that no significant impacts will result from park application of sludge. This safety margin will be necessary because particles of sludge will probably be ingested by some picnickers, children playing in the dirt, etc.

In view of the differences in pathogen viability and concentration in the different types of sludges (liquid, air-dried and stockpiled for various lengths of time), their respective uses should be limited appropriately. For example: (1) liquid sludge should be applied only by deep injection into the soil, with no possibility of surface exposure; (2) as the level of human contact becomes more probable for each use (dry farms, irrigated farms, home gardens, vegetable crops, in increasing order), required length of storage time in the drying and stockpile areas should be increased.

Nitrates--

Potential pollution of groundwater will not pose a significant public health hazard. The primary chemical constituent of concern is nitrate. Nitrate levels over 45 ppm (measured as nitrate) in drinking water are considered to be harmful to infants (Reference 112). However, as indicated below under Water Quality, groundwater contamination under most land recycling schemes would be less than or the same as from use of commercial fertilizers.

Health Services--

A significant impact upon the public health department services is foreseen as a result of the proposed project. The public health department's monitoring activities will need to be expanded to cover all the land recycling areas receiving sludge. This will increase the manpower requirements of the public health services.

Water Quality

Two potential water quality hazards posed by sludge amendment of soils are the total dissolved salts (TDS) and the nitrate form (NO_3^-) of nitrogenous compounds found in the sludge and supernatant liquid. If the supernatant is excluded from the land application project, salt problems will largely be prevented. The nitrate pollution of groundwater and surface water remains as long as there is a supply of nitrogenous compounds over and above the amount which plants can take up and denitrifying bacteria in the soil can denitrify. Water pollution hazards posed at the six typical sites studied are presented separately below, in order to emphasize the specificity of impacts to sites and conditions as well as the typical management practices employed.

City Parks--

Of the approximately 500 known wells within the City of Denver, in 1964 (Reference 21) fewer than 50 were used wholly or in part for domestic purposes. Most wells are used for irrigation, cooling water, industrial and other purposes.

It is expected that at the proposed annual sludge application rates of 56 metric tons/ha [25 tons/ac] per year and with the typical irrigation practices on park lands, significant quantities of dissolved salts, including nitrates, will leach toward the groundwater reservoir. In about 20 to 100 years these salt-laden seepage waters will arrive at the groundwater table and will gradually increase TDS and nitrate concentration of waters withdrawn from the wells. It is probable--though supportive data are lacking--that even under past and present commercial fertilizer regimes, downward movement of nitrates have been and are proceeding. Therefore, earlier arrival of nitrates in the well waters should be expected.

If domestic uses of groundwaters (for drinking and culinary purposes) are altogether prohibited or otherwise terminated, the recommended limit of 45 mg/l of nitrate nitrogen may be permitted to be exceeded in the groundwater. If, on the other hand, domestic uses of groundwater in parts of the Denver area are indispensable, sludge and fertilizer application rates should be limited to levels recommended in Section IV. Limitation of sludge application, particularly in those parts of the City and County of Denver and other cities using groundwater for drinking purposes, is very important and necessary for public health protection. Sucy controls should probably be made in conjunction with controls for irrigation leaching.

Pollution of surface waters, such as streams and lakes in the City, through leaching and/or runoff is a distinct possibility. It can be minimized through erosion control and judicious choice of sludge application rates and methods to balance uptake of salts by plants.

Sod Farms--

It is expected that with adherence to the recommended sludge application rates (in Section IV) negligible nitrate leaching to the groundwater will result. Other soluble salts, however, will gradually move downward with the irrigation waters applied over and above the evapotranspiration needs of the grass. The amount of these salts applied with the sludge is expected to be relatively moderate (about 350 kg/ha [300 lb/ac] per year) and significant only from a long-range cumulative point of view.

Surface water contaminations from portions of the sod farm that are actively growing grass will be insignificant, because of the highly effective cover that sod provides against runoff and erosion. The soil in the sod farm studied, Truckton sandy loam, is erodible unless it has adequate cover. Therefore, without some provision for catchment of surface runoff, pollution of streams may be expected from portions of the sod farms which have just been harvested or which have been left unplanted.

Mine Spoil Sites--

The thickness of spoil materials heaped on top of the natural ground surface ranges from a few meters at the minimum to about 80 m [250 ft] at the top of the spoil banks. Irrigation water and rainfall can travel through these highly porous materials with relative ease after the rocks reach saturation moisture content. It is expected that the more successful the reclamation of spoil banks is, the less excess water will be available to leach through the acidic spoil materials and the less mine spoil drainage will take place. Irrespective of pollutant constituents of applied sludge, mine spoil drainage is generally a severe contaminant of surface waters. Hence, use of sludge to slow down such drainage through entrapment and evapotranspiration of precipitation will help mitigate an existing major water quality hazard.

At the modest application rates proposed, especially with the use of wood chips (with high C:N ratio, helping immobilize nitrogen from the sludge), it is expected that nitrate movement below the root zone will be minimal, if any. Heavy metals will probably remain within the developing soil and become immobile and unavailable if pH is maintained above 7.

Irrigated Farms--

Irrigated farms generally possess some tailwater control provisions and are designed to achieve high water application uniformities and efficiencies, resulting in minimal wastage and control of excessive deep seepage. With the use of sludge on these farms, these controls are even more important. Otherwise, (1) excessive seepage will result in groundwater contamination with nitrates and soluble salts, and (2) runoff could lead to direct transport of sludge solids and soluble materials to the surface water courses.

It is difficult to quantify the precise impact of sludge application on water quality. The impact is not only a function of how well the recommended application rate limits are followed; it is also determined by the manner in which other standard farming practices (irrigation, drainage, tillage, etc.) are performed. It can therefore be surmised that the more sophisticated and successful a farming operation is, the less are the chances for sludge application on that farm to pollute water resources. The converse would hold true for poorly managed and operated farms. Therefore, it is important that a judicious selection procedure be set up and the material not be given simply to whoever asks for it. Binding agreements, permitting the District representatives to conduct monitoring and inspection services, will help guarantee against large-scale contamination of the water supplies.

Home Gardens--

If large numbers of homeowners and gardeners adopt sludge amendment practices, some water pollution could occur. Ornamental plants and vegetables are typically heavily irrigated and very often over-irrigated. Therefore, both deep seepage into the groundwater reservoir and runoff toward surface streams occur on a regular basis, contributing to urban non-point runoff. Opportunities for improperly high application rates and consequent degradation of water supplies are thus abundant in this type of recycling of the sludge. However, the total amount of sludge thus used should be relatively small and will be highly dispersed.

Soil Properties

Once sludge enters the soil, its impacts upon the various components of the environment become indistinguishably interdependent. Thus, while this discussion is divided into separate topics for clarity of presentation, the interdependence of the physical, chemical and biological properties of the soil and crop responses, as well as animal and human reactions to eating the crops and animal tissues, should be clearly recognized.

Soil Productivity--

It can be expected that soil productivity will increase with properly controlled and managed sludge application to any of the proposed sites. Many experiments with sludge application to soil have borne out this conclusion (References 121, 122 and 123 to cite a few), and some have shown increased productivity even above that which could be expected from equivalent chemical fertilizer applications (References 81 and 124). The short-term annual increases in yield, attributable to annual and residual releases of sludge nitrogen, phosphorus and other essential elements, are by no means the only contributions to soil productivity. A long-lasting impact of sludge application to soils is the gradual increase in the organic matter content of the soil root zone. As described below under Soil Structure, the increase in organic content leads to improved root penetration and other enhanced conditions for plant growth, ultimately resulting in increased yield and productivity.

SOIL STRUCTURE IS ENHANCED BY SLUDGE

If application procedures do not guard against uneven spreading and variable incorporation of the sludge into the topsoil, the same types of problems as are associated with uneven fertilizer application may be expected. A typical problem is non-uniform soil fertility, resulting in uneven growth, maturation and yield. The commercial equipment available, if properly operated and maintained, can provide reasonably uniform spreading of the dry sludge. Liquid sludge injectors which concentrate applications in a band along the cutting "knife" will tend to produce a corrugated growth and yield pattern during the first few years unless successive injections are performed in a criss-cross fashion.

Liquid sludge usually has a higher nitrogen content than dried sludge and should be applied at correspondingly lower surface loading rates. Furthermore, liquid sludge tends to inhibit germination and to impose initial toxicity to young plants. Damage can be caused by excessive concentrations of ammonia, salts and organic compounds or by creation of anaerobic conditions in the root zone which reduce soil microorganisms and deplete oxygen in the soil. The precise cause of initial organic toxicity has not yet been established. At recommended application rates, this initial toxicity will be limited to the immediate areas of application for only short periods of time. If injection of liquid sludge is limited to periods far enough in advance of the growing season, the toxicity problem and related reduction in productivity will be minimized.

Phosphorus content of Metropolitan Denver sludge averages about three percent of the dry solids (Reference 5). Within the recommended range of sludge application rates on irrigated farms, 8 to 35 metric tons/ha [3 to 16 tons/ac], about 240 to 1,050 kg/ha [180 to 960 lb/ac] of phosphorus (as P) is applied to the soil. These excessive amounts of phosphorus would be potentially toxic to plants were it not for two important considerations. First, phosphates in the sludge are primarily in the precipitated form and thus are not immediately available for plant uptake. Second, the calcareous nature of soils in the irrigated farms, for the most part, provides a ready mechanism for formation of insoluble calcium phosphate forms which release available phosphorus to plants over a long period of time. An important advantage of the high phosphorus content of the sludge is its reported ability to reduce the availability of zinc and nickel in the soil (Reference 124).

An important aspect of increased fertility--particularly nitrogen availability--is that continuous nitrogen availability may make certain management practices more difficult. For example, in sugar beet culture, farmers have learned that by with-holding nitrogen and water in the last stages of growth, prior to harvest, they can increase sugar content of the crop. With the use of sludge, this type of ready control of available nitrogen may become difficult, if not impossible. The Great Western Sugar Company of Longmont, Colorado is presently conducting controlled experimentation with the use of sludge on sugar beet farms (Reference 125). Other effects of continuous availability of nitrogen, such as plant lodging, delayed maturation, color development of certain fruits, etc. generally do not apply to the types of crops commonly grown in the study area.

Soil Structure--

The anaerobically digested sewage sludge contains stable humus-like organic compounds which resist decomposition, particularly under irrigated farming conditions. These molecules, when well incorporated into the soil, tend to bring about changes in soil structure which have long-term beneficial effects upon the physical properties of the soil. The importance of organic matter to soil conditioning has long been recognized by farmers who have been applying barnyard manures, compost and other organic wastes to soils since time immemorial.

The principal change occurring as a consequence of organic matter additions to the soil is the gradual formation of a loose, friable soil structure, contrasted with the massive structure of clayey soils and the granular character of sandy soils. Increased organic content reduces the possibility of formation of shrinkage cracks in clay soils and gives a more cohesive character to sandy soils. Epstein (Reference 126) found a doubling of the percent of stable aggregates in a soil amended with sludge over a period of 175 days. Organic matter increases the water-holding capacity of the soil; organic soils can retain more than their own weight of water against gravity drainage, while a sandy loam soil may hold less than ten percent water. Thus, successive applications of sludge over the years slowly builds up the water-holding capacity of the soil so that irrigation intervals may be increased, unwanted leaching of excess water reduced and plant growth and yield generally increased.

The improved soil structure enhances root penetration and vigorous growth throughout the soil profile, leading to generally healthier, more vigorous plant growth and increased crop production.

Soil Permeability--

Movement of water through the soil is governed principally by soil texture, structure, organic matter content, and the degree of aggregation of clay particles. Application of sludge to soil can change the latter three parameters drastically, giving rise to significant changes in permeability of the soil. Epstein (Reference 126) reported an initial increase in permeability of a sludge-amended soil followed by a return to initial values. Presumably, the initial increase occurred due to improved soil structure, and the subsequent decline was caused by clogging of pores. Although unsaturated hydraulic conductivities were not measured, it is surmised from increases in water content at all soil-water tension ranges that these conductivities probably increase with addition of sludge to soil. The increase in unsaturated conductivities is important *vis-a-vis* water availability to plant roots because, commonly, unsaturated conductivity is the limiting factor in moisture transport within the root zone.

Soil Erodibility--

Formation of stable aggregates, discussed above, helps increase soil resistance to both wind and water erosion. Additions of sludge over a number of years gradually reduces soil erodibility and thus provides a self-correcting mechanism against contamination of surface waters in addition to conserving topsoil. Many of the soils in irrigated areas are naturally moderately to highly erodible in the absence of plant cover. Over the years, sludge application can significantly reduce soil erodibility in these areas.

Salt Accumulations--

Liquid sludge from the Metro Denver Central Plant contains about 6,000 mg/l total salts, with only 180 mg/l sodium and 140 mg/l chloride. Salt accumulation in the topsoil can be regulated with proper irrigation and drainage practices. As long as the necessary leaching fraction of the total irrigation water requirement is provided, there should be no excessive salt buildup.

Given a total dissolved solids concentration in liquid digested sludge of about 6,000 mg/l, it can be calculated that on the average about 350 kg/ha [300 lb/ac] of salts will eventually move into the groundwater reservoir. These salts will be transported horizontally to downstream areas until the water is pumped out again for irrigation or other uses. Thus, over a very long period of years (perhaps centuries), it can be expected that salt buildup in the whole ecosystem will be inevitable. Therefore, irrigation water salt contents will increase gradually. Even though specific areas of sludge reuse will presumably be returned to non-sludge culture after the limit surface application rates are reached, the salt content of the whole region will inevitably rise over the long term, as new areas are brought into sludge application culture. A more recent discussion of soil salinity is presented in Volume II, Issue V-1.

Soil Impacts on Specific Sites--

The general effects of sludge application on soils, presented above, are applicable to nearly all types of sites, but are most representative of the irrigated farms and home gardens, whether ornamental or food crops are raised. Specific variations from these generalities can be expected at other sites due to the differing water regimes and other management differences. These variations are summarized for city parks, sod farms, mine spoil sites and non-irrigated farms.

City Parks--As discussed under Environmental Setting, most of the City parks are constructed upon fill material from other areas, landfill covers, construction debris and imported topsoil. Therefore, there is practically no indigenous soil profile to be affected, directly or indirectly, by the sludge application and reuse scheme. The pre-planting use of sludge and the proposed annual additions will aid in the formation and improvement of supportive substrata for City park plantings. Improvements in soil structure, water-holding capacity, root penetration, erosion resistance and permeability will occur, in similar fashion to those discussed above.

It is expected that much higher total ultimate loadings of heavy metals can be allowed in City parks "soils" than in areas intended for food production. Grasses and other plantings on park sites are generally more tolerant to higher concentrations of heavy metals in the soil. Maintenance of high pH through a regular liming program along with sludge application may be indicated through testing of soil pH on individual parks. Use of sludge on City parks subjected to a great deal of foot traffic and compaction can be particularly effective in improving soil aeration and water penetration.

Sod Farms--The unique harvesting operations at sod farms involve the removal of a thin layer of soil (2 to 3 cm [0.8 to 1.2 in.]) every year. With this layer, most of the added organic matter and its constituents contributed by sludge are removed to their ultimate location of use. Thus, most of the direct soil-building potential of the applied sludge is transferred to the ultimate consumer of the sod. Since the amounts of sludge involved in one cycle of sod production are relatively low, it is not expected that the effect upon soil structure, permeability, and other physical characteristics will be significant unless the consumer also applies sludge or other humic matter to the lawns.

The short-term positive impact on productivity is quite significant and can exceed that of equivalent quantities of commercial fertilizers. No significant salt buildup in the soil is expected.

Mine Spoil Sites--Since at present there are no soils on the surface of the mine spoil sites, no soil impacts are associated with sludge application to these sites. Natural soils are buried beneath a great thickness of mine spoil materials. Considerations for soil building and reclamation of the sites to permit the natural succession of plant species are presented below under Flora and Fauna.

Non-Irrigated Farms--The relatively low sludge application rates recommended for non-irrigated farms and drylands make the soil impacts relatively minor. The amount of organic matter contributed by sludge will average less than 0.1 percent of the plow layer mass per year. Furthermore, because of the dry conditions, organic matter will be oxidized and destroyed more rapidly than under irrigated conditions. Hence, it is not expected that any perceptible improvement in soil physical conditions will materialize as a result of sludge reuse. Short-term soil fertility, however, will increase dramatically due to rapid availability of adequate quantities of nitrogen and other essential nutrients.

Use of liquid sludge usually gives rise to an initial toxicity whose basic mechanisms are not yet well defined. Special tools for placement of liquid sludge in separate bands below the soil surface have been developed and tested. This type of liquid sludge application, while conserving the maximum nutrient potential of liquid sludge, minimizes initial toxicity by permitting roots to grow around the sludge areas rather than be confined thereby, and therein. It is expected that future experimentation at the drying and distribution center will increase knowledge of soil fertility/toxicity tradeoffs of the various application tools.

Heavy metals accumulation in soil will proceed at a rate far lower than that of irrigated farms. These metals will have adequate opportunity to "revert" to unavailable forms in the calcareous soils typical of non-irrigated farmlands. It is expected that long before critical limits of these metals (defined in Section IV) are reached, industrial effluent exclusion or reduction schemes will have been instituted and implemented in the Denver area, permitting almost unlimited periods of sludge reuse.

Salt accumulation in the topsoil may become a problem after many decades of sludge application. Although annual salt accrual rates are much lower than in irrigated farms (less than 20 kg/ha [20 lb/ac]), lack of irrigation water, paucity of rainfall and the predominance of evapotranspiration rates all help keep salts in the root zone of the soil. It would take about 200 years, at the recommended sludge application rates, for soil salt content to reach levels which would reduce crop yields significantly. Thus, it appears that, instead of heavy metals, soluble salts impose the upper limit on ultimate surface application rates of sludge in non-irrigated farms and other drylands.

Air Quality

If dried sludge is left on the surface and subjected to blowing in the wind, hazardous air pollution conditions could occur. Lead content of sludge is the most important constituent in the airborne assimilation of sludge particles by humans, conceivably causing cumulative toxicity to frequent passersby. Other heavy metals in sludge, as well as any surviving microorganisms, including spores and eggs of parasites, could also be transmitted by aerosols. It is expected that proper application timing, supplemental sprinkling, and mechanical incorporation of sludge into the soil will effectively eliminate the air pollution potential of sludge reuse.

Odors--

Air-dried digested sludge, taken from the stockpiles, is expected to be nearly odorless. When broadcast at the recommended surface application rates and incorporated into the soil, it is not expected that odor from the sludge will be detected at the boundaries of the application sites except by those most sensitive.

Liquid sludge, if applied with subsurface injectors (equipment is manufactured by at least two companies in the Denver area), will have no noticeable odor even at close proximity to the application equipment. Spraying of the liquid sludge on the surface with special spreaders behind tank trucks will produce temporary odors at close proximity to the application areas. The higher the application rate and the longer the sludge remains on the surface before incorporation, the worse the odors produced will be. On the whole, however, anaerobically digested sludge is stable enough so that the odors produced are not very strong or offensive.

The city parks and home gardens would be potentially the most odor-sensitive application sites. However, the fact that sludge has been applied to the parks for years with no significant complaints is a good indication that continuation with digested air-dried sludge will have no significant odor impacts.

There may be some odors the first day or so after a large amount of sludge is spread on parkland. This smell, which most do not find particularly offensive, may carry for about a block. The past practice of applying the sludge during low-activity periods in the park reduces the airing-out period. Similarly, applying the major portions in the winter when people tend to be indoors has effectively limited the number of complaints.

If any publicity is given this application practice, past experience has shown that there will be a temporary increase in odor complaints following the publicity. Lately, sludge use has become more commonly accepted as a positive conservation-minded practice.

It is expected that odor produced by sludge application to such other sites as sod farms, mine spoil sites and other farms will be of minor significance due to the relative isolation of such sites and the presence of other normally associated odors (e.g. manure on farms).

Air Quality Impacts on Specific Sites--

Each site offers special opportunities and limitations insofar as air quality impacts are concerned.

City Parks--It is expected that quick incorporation of sludge into the seed bed, at the initial stages of park establishment, and into the turf during the annual winter applications will minimize air pollution hazards from this source. The high accessibility of these parks to human beings and the proximity of residences make the potential impact on air quality quite significant. Dried sludge, blowing from the trucks as it is hauled to the City parks, could, if not controlled, have highly undesirable air quality impacts.

Sod Farms--Small quantities of particulate material may be released to the air during and immediately after application of the dried sludge material. These effects may be heightened in the presence of strong winds, especially during seed bed preparation in the spring. The frequent irrigation associated with sod farming would reduce the effect of dust blowing to insignificant levels. The remoteness of sod farms further mitigates air quality impacts.

Mine Spoil Sites--The proposed reclamation of mine spoil areas is typically relatively short term. Small quantities of dust may be released to the air during and immediately after the laying of fine rock material and composted sludge. This effect may be increased if winds are strong. However, subsequent operation of an irrigation system and growth of plants will mitigate this effect.

The quantities of dust thus generated would only be a short-term contribution to the air quality of the mine operations and would be relatively insignificant, especially in view of the remoteness of these sites from human exposure.

Irrigated Farms--Sludge application on irrigated farms is not expected to give rise to deterioration of air quality if soil incorporation of sludge and proper mixing are achieved immediately upon application. A significant threat from improper application procedures, i.e. leaving dried sludge on the land surface, especially in windy conditions, can arise with the dispersal of particulate matter on and beyond the farms. Immediate mechanical incorporation of sludge into the soil, followed by irrigation (or a fortuitous rainfall), can control or minimize air pollution from this source.

Non-Irrigated Farms--The threat of particulate dispersal from non-irrigated farms and other drylands treated with dry sludge is rather severe. No matter how well dry sludge is incorporated with the soil, the dry nature of these lands will permit dust blowing during severe winds.

Application of liquid sludge, on the other hand, with deep injectors, will alleviate this problem altogether. This is particularly important as dryland farms generally have soils whose deeper strata are highly calcareous and can rapidly make heavy metals unavailable. The binding effect of sludge on soil particles promotes aggregate formation and reduces the potential for the soil to become easily airborne in moderate winds.

Flora and Fauna

Impacts of sludge application to land on vegetation and wildlife is so highly site-specific that no attempt is made here to make any generalizations. At the risk of a few repetitions, impacts are qualitatively described for each site under a separate subheading. Impacts on vegetation are further discussed in more detail in Appendix D.

City Parks and Home Gardens--

Vegetation--Application of sludge to vegetation in the City parks and home gardens should have beneficial impacts by stimulating plant growth. Sludge contains all of the elements that are essential for plant growth, and with proper application will serve as an effective fertilizer.

Any adverse impacts resulting from sludge application would be caused by excessive rates of application. Grasses are tolerant of heavy metals and have a high rate of nitrogen uptake. The periodic mowing of grass will remove appreciable quantities of salts and nutrients that have accumulated in the plant tissue. The salts thus removed will probably be deposited in contained sanitary landfills.

Grasses are effective in the control of erosion and runoff. Surface runoff from the land would be minimized with a vigorous cover of grass.

Wildlife--Broad scale sludge applications would probably occur in the late fall and winter during periods of minimal park usage. Sludge application, even on snow-covered areas, followed by further snowfall, minimizes the direct contact time for wildlife and humans. Overall bird populations are lower during the fall and winter, with the exception of wintering species and semi-domesticated species such as rock doves.

Sludge incorporation into the soil would probably have similar effects on burrowing and ground-dwelling rodents, as discussed further below under wildlife impacts at the Lowry Bombing Range. The effects may be less pronounced due to the controlled sludge application rates and rodent control programs.

Seed bed preparation with sludge supplement occurs generally in the spring and late fall. Bird species which forage on the ground--such as robins and towhees--and feed upon terrestrial insects and seeds are exposed to the sludge mixture the most. These birds may be exposed to a slight concentration of sludge components along the food chain. However, these birds are not confined to the City parks area and range throughout the urban areas. Animals, including dogs, may be exposed to pathogens and parasites by direct exposure and ingestion.

Sod Farms--

Vegetation--The use of sludge as a fertilizer and soil conditioner on sod farms will have beneficial impacts on sod production. Sludge contains all the essential plant nutrients, and in some cases sludge has been shown to generate higher crop yields than commercial fertilizer. Grass is a good crop for sludge fertilization because it is tolerant of heavy metals, is not used as feed or food, has a high rate of nitrogen uptake and minimizes problems from runoff and erosion.

Wildlife--Due to the intensive management of a sod farm, direct effects of sludge application upon wildlife would be few and probably limited to spring and fall during times of seedbed preparation. Bird species which forage on the ground--such as meadowlarks and sparrows--feeding upon terrestrial insects and grass seeds, are exposed greatly to the sludge mixture. Heavy metals and other sludge constituents accumulated by insects may be further concentrated by bird predation. On a well-maintained sod farm, however, thick sod growth effectively minimizes uptake of sludge constituents by insects. The monoculture of selected short grass species also represents an unbalanced ecosystem with only a few insect and bird species. Small rodent problems on a sod farm are also minimal due to the poor burrowing quality of a thick, fibrous turf and constant disturbance and "grazing pressure" of mowing equipment. Thus, incorporation of sludge constituents by small rodents would not be a problem on this type of site.

Mine Spoil Sites--

Vegetation--The land application of stabilized sludge mixed with wood chips to mine spoil sites will have very beneficial impacts on vegetation. Since mine spoil sites are typically devoid of a substrate capable of supporting plant growth, the land application of composted sludge would essentially be a soil building process.

Climax Molybdenum proposes to transport a total of 90 metric tons/ha [40 tons/ac] of sludge mixed with wood chips (in a 1:1 ratio) to the mine spoil sites. Assuming that this material has a density of 400 kg/cu m [25 lbs/cu ft], the total amount of composted sludge to be applied will have a depth of 2.3 cm [0.9 in.] before incorporation. Proper substrate building procedures for vegetation establishment should include: (1) application of smaller rocks above larger rocks; (2) application of well-graded materials such as finely crushed rock and sand to a depth of 25 to 30 cm [10 to 12 in.]; (3) application of the sludge-wood chip mixture and (4) incorporation into the top 15 cm [6 in.] of the finer material. In this way, the top layer of "soil" will contain approximately 13 percent organic matter after total composted sludge application. This is a high percentage of organic material and should provide a good substrate for plant growth.

The establishment of a ground cover would probably follow the basic pattern of plant succession. Hardy pioneer species would first become established and would slowly build up the depth of the soil profile over time through decomposition of dead material, thus permitting the growth and establishment of a more diverse plant community.

Plant succession is generally an extremely slow process. The rate of succession would depend on such factors as the amount of sludge and other materials applied and the types of plant species that are initially planted. Grasses are relatively easily established, but they do not provide large amounts of organic material to be decomposed. Some native shrubs such as bear berry and buffalo berry, which are presently growing on the Urad Mine spoil site, might be planted with some success. These would provide more substantial amounts of detritus in the form of leaf litter than would grasses, although their rates of growth might be inhibited at first by the penetration of the roots deeper into the soil profile. Trees might also be planted, although the penetration of their roots through the top layer into the coarse and acidic spoils might limit their growth potential for many years.

Because the total amount of sludge to be applied is relatively low, the uptake of hazardous heavy metals, such as cadmium, zinc, copper and nickel, should not present problems to plant growth. Plant growth might be inhibited, however, by the uptake of heavy metals present in the underlying spoil material, although this situation should be alleviated over time as the soil profile increases in depth.

The establishment of a complete groundcover of vegetation is highly desirable since it can result in (1) earlier soil stabilization and reduction of erosion; (2) earlier mitigation of acid drainage in surface runoff through increased water holding capacity and through increased water use by evapotranspiration; (3) acceleration of the accumulation of organic residues which will chelate or otherwise make unavailable the soluble iron, manganese and aluminum. Organic residues also provide the necessary seedbed for plant germination.

Wildlife--Mine spoils areas are typically rocky, barren and devoid of normal signs of life. Application of sludge with incorporated wood residues would be an initial step towards the reclamation of these wastelands. The successful establishment of vegetation over a period of time would help to restore some of the habitat that had been destroyed by mining activities.

Wildlife habitat would be minimal due to the severity of the terrain and presence of limited types of vegetation. However, the distinct transition from forested slopes to a broad open swale with grass and shrub vegetation would provide an "edge" habitat favorable to wildlife. Animals feeding upon vegetation in the reclaimed mine spoils area are subject to accumulations of trace elements as discussed under Food Chain, above.

Limited sludge applications for only two years at relatively low rates greatly reduce the potential for hazard. Within 3 to 5 years, a permanent ground cover could be established. Although this habitat will not be very diverse, the variation it provides in the heavily-forested woods and Clear Creek Canyon is an important ecological consideration. With the decay of the mine spoils and long-term formation and maturation of soils on the site, larger and more sensitive vegetation forms may become established. Thus, in the long term, partial or full reclamation of the mine spoil sites would provide new wildlife habitats and an overall benefit to wildlife.

Irrigated Farms--

Vegetation--Areas of irrigated farmland that are subject to the application of sludge are necessarily under cultivation and contain no native vegetation. In general, sludge will have beneficial effects on plant growth by supplying all of the essential plant nutrients. The accumulation of hazardous heavy metals in plants reduces the yield significantly before these metals become a danger to the food chain if the cadmium/zinc ratio is less than one percent. In the Denver sludge, this percentage is about 1.7 and poses a potential minor hazard.

Selection of crops suitable for growth on sludge-enriched soils should be made in consultation with the local extension service of the U.S. Department of Agriculture. Plants vary widely in their reactions to sludge application, and these reactions are site-dependent. Crops that are grown for their seeds or fruit rather than for their vegetative tissue and crops whose younger rather than older vegetative tissue is utilized are more desirable in terms of trace element accumulation.

Wildlife--Insect populations and scavenging wildlife will constitute a problem on sludge-amended farms, depending on the type of crop grown. Large stands of monoculture represent a greatly simplified ecosystem with a preponderance of only a few insect and animal species.

Plants differ widely in accumulation of heavy metals and other materials. Zinc and copper in very small amounts are micronutrients beneficial to the animal and human diet (Reference 127). Evaluation of potential effects of sludge on wildlife and on domestic animals requires individual analyses of farms and of crop types and their ability to accumulate trace elements. The greatest concern is for grazing animals who will consume forage crops such as hay and alfalfa grown on sludge-aided soils. Copper would be a special hazard to grazing animals if sludge of high copper content were sprayed on established pastures (Reference 128). Leaf surface copper is rapidly washed off with rain or irrigation water but remains a hazard until removed. "Dietary copper and molybdenum interact in the ruminant. When the molybdenum content of forage is known to be low, expected increases in copper content of some forages could be hazardous to sheep, while in forages of normal molybdenum content copper can be considerably higher" (Reference 128).

Insects and small mammals dwelling in or feeding upon irrigated croplands are also subject to accumulations of trace elements and other materials. Foliage-eating insects and burrowing rodents such as gophers are particularly susceptible. These secondary consumers in turn support upper levels of the food pyramid.

Non-Irrigated Farms--

Vegetation--The impacts to vegetation on dryland farms are the same as those discussed under Irrigated Farms. Agricultural effects of sludge application are discussed in detail in Appendix D. In general, dryland farms will sustain a lower rate of sludge application than irrigated farms because the rate of nitrogen uptake of dryland crops is much lower than that of irrigated crops. Seed germination can be inhibited if planting operations are conducted too soon after liquid sludge application. If planting is done from two weeks to one month after low-rate sludge application, seed germination is uninhibited.

Wildlife--Sludge application would occur in the spring or fall during seedbed preparation. Application rates are generally much lower than on irrigated farms or sod farms. Sludge constituents are less likely to accumulate in the wheat and barley crops typically grown in dryland farming. Thus, the hazards of high concentrations of trace elements are less significant. The minimum supervision and low maintenance required for a dryland farm allow the fields to remain relatively undisturbed for long periods of the year; thus, dry fields are easily incorporated into the ecosystem and are suitable for wildlife habitat. Mice, gophers and jackrabbits particularly utilize this environment and will be constantly in contact with the sludge-treated ground. Acute effects of grazing upon the vegetation are discussed above under irrigated farm impacts. The low application rates and low uptake of trace elements generally do not constitute a great hazard to wildlife on a dry farm.

Grazing animals and wildlife may be exposed to pathogens and parasites by direct exposure and ingestion. Pathogen survival is greatly reduced by stabilization; however, some parasite ova such as *Ascaris* may remain viable for many years in the soil.

Noise

Noise generated by sludge application (broadcasting, injection or spreading) equipment is expected to be similar to that produced by similar farm and landscaping equipment, such as tractors, trucks and manure spreaders. Therefore, no particular noise impact is anticipated. Some reduction in noise may be expected to the extent that sludge application replaces fertilizer and/or manure application on these operations.

In city parks, equipment and heavy machinery for applying the sludge would generate noise levels that may be incompatible with residential areas. This noise generation is unavoidable, but is generally limited to short durations a few times per year. The sludge application process is only a fraction of the parks maintenance program and, to some degree, is acceptable in consideration of the benefits to vegetation and overall maintenance of the City parks system. Use of mufflers on such equipment can inexpensively mitigate this minor problem.

In sod farms, irrigated farms and dryland farms, continual operation of farm equipment and the attendant machine noises during the growing season are an integral part of the farming operations. Some additional noise will be introduced by sludge transport trucks delivering the sludge to remote plains areas. In perspective, sludge transport and application would only be a small fraction of farm operations. The local climatological conditions and openness of the plains help to disperse sound well. In addition, the low population density and isolation from other noise sources make contributions from this part of the project insignificant.

In mine spoil sites, noise generated from sludge transport and application operations would by typically on a one-time basis. The narrow valleys, steep grades and heavily forested slopes tend to confine noises within the local area. Noise generated during sludge application and area seeding and planting would be greatly masked by the noise from ore processing machinery at the molybdenum mine. Therefore, noise contributions from sludge transport and mine spoil reclamation would be relatively insignificant.

In home gardens, sludge application would probably be performed with small hand-operated equipment. Noise from such machines as rototillers might disturb neighbors for short periods of time.

Aesthetics

Since people generally accept the fact that fertilizer must be applied to the lawns and gardens of the parks, and since the dried sludge does not have a particularly offensive appearance, no significantly adverse visual impacts are expected from the continued application of the material to the parks. As an added precaution to avoid offending anyone's aesthetic sensibilities, the Park Department attempts to apply the material during seasons and times of the week when park use is low. Applying the black material to snow-covered lawns in winter would make it highly visible until the next snow.

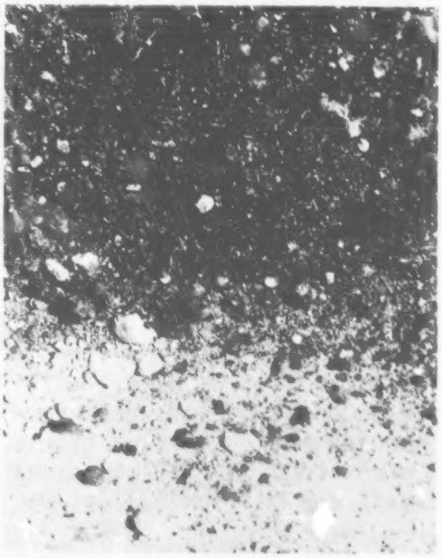
Application of sludge to mine tailings has a beneficial aesthetic impact since it prepares the barren spoil areas for the grass and tree plantings, examples of which are now successfully in progress.

It is expected that the inert appearance and the nearly odorless characteristics of the dried sludge will help overcome the psychological image associated with the fecal origin of the material. Positive experience with sludge over a period of several years might reduce the negative aesthetic impact.

Natural Resources

The resource value of sludge is discussed at length above, under the drying/distribution site impact analysis.

Intensive farm operations (such as sod production and other irrigated agriculture) can deplete natural resources over large areas. The rapidly growing plants extract large quantities of nitrogen and other elements from the soil. In addition, thin layers of soil material are removed from the sod farms during harvesting. Without soil supplements or some form of compensation, a sod farm could deplete the soil resource in a relatively short time. Sludge applications would serve not only as a fertilizer but also as a soil



DRIED SLUDGE

conditioner. Dried sludge is high in nitrates and contains other macronutrients and trace elements required for plant growth. Periodic cropping and annual harvesting can remove some accumulations of trace organic materials. However, the long term accumulation of salts and trace elements may preclude sludge applications after a finite period of time, as discussed in Section IV. Therefore, with controlled applications over a long period, sludge reuse on farms can help maintain the soil resource.

Mine spoil areas are generally highly disturbed areas with effectively few resources. The application of sludge to these waste areas is the initial step towards reclamation of the areas. Establishment of ground cover will eventually lead to the buildup of a stable ecosystem. While the reclaimed areas may never be able to duplicate the original ecosystem, they would constitute a vast habitat improvement for wildlife resources and the natural system. Thus, the proposed action would accrue an overall benefit by partial restoration of natural resources.

Traffic and Circulation

Most of the sludge application sites will not be significantly affected insofar as traffic and circulation patterns are concerned. For example, if the City and County of Denver Park Department ultimately utilizes 4,500 metric tons [5,000 short tons] of dried sludge as anticipated, average daily trips will increase annually by 200 (References 40, 77). Since travelways such as Irondale Road and connecting major highways near the Denver urban core are adequate in design to accommodate this minimal increase, no significant impact on transportation and circulation patterns will ensue should the proposed project be implemented.

Agricultural Economy

The agricultural economy in the area will be aided by the proposed project, since it will provide a local source of fertilizer/soil conditioner, a resource in increasingly short supply. The nutrient benefit value of the design production capacity of 97 metric tons/day [107 tons/day] of dried sludge solids is worth at least one million dollars per year at present prices.

The productivity increases resulting from sludge application will undoubtedly vary among the individual farms using the material. However, field tests by Metro Denver have verified the general increased productivity results achieved elsewhere with agricultural use of sludge. For example, in well-managed sludge application programs there have been 2- to 4-fold increases in forage production, 2.5-fold increases in wheat production, and 20 percent higher corn yields than were achieved by commercial fertilizer (Reference 81). Mismanagement of the sludge application on farms could have adverse economic impacts. Application rates in excess of those recommended by the soil scientists and agronomists could limit productivity due to high nitrate or heavy metal levels.

A small benefit to the farmers in this somewhat arid region is the fact that the "dried" sludge will be about 50 percent water. Assuming design capacity production at 97 metric tons/day [107 dry tons/day] of dry matter in the sludge, there would be about 36,000 cu m [30 ac-ft] per year water in the sludge. This is a relatively small amount of water and will be distributed very thinly over a relatively large area.

Land Values

The proposed project is expected to provide a free or inexpensive fertilizer/soil conditioner for agricultural operations within the delivery area of the sludge drying/distribution center. This will probably have a positive impact upon land values, based on the assumption that the sludge will improve the productivity of the lands which receive it. This assumption seems justified by the evidence from other areas which have used anaerobically digested sludge as fertilizer.

Chicago and Orlando are two of a number of cities which have demonstrated the agricultural benefits of controlled land application of sludge for crop production. Denver, San Francisco, San Diego, New York, Las Vegas, Miami and other cities have used wastewater treatment plant sludge for park and lawn development. In other countries too, sludge is used for agricultural purposes (examples are Melbourne, Australia; Leipzig, Germany; and the West Hertfordshire Main Drainage Authority in London, England). Increases in land values in sludge application areas are in part attributable to improved productivity of the land.

Summary of Land Application of Sludge on the Recycling Areas

The most potentially severe negative impacts are in the food chain due to heavy metals uptake by plants and animals. Public health hazards and water quality problems also rank quite high in potential adverse impact. The worst application sites vis-a-vis reuse of sludge are home gardens, city parks and irrigated farms, while the best sites are mine spoil sites, sod farms and dry farms. The greatest beneficial impacts are in improved soil productivity and conservation of resources. A schematic representation of the impacts at various sites is presented on Figure 17 (page 138).

IMPACTS OF SUBSURFACE INJECTION OF LIQUID SLUDGE AT THE DRYING/DISTRIBUTION CENTER

The Metro facilities plan called for the injection of some of the liquid sludge on a 24 ha [60-acre] portion of the proposed site. The area was contemplated by Metro to be both a demonstration area and a possible secondary disposal area for excess sludge.

Metro's current plans call for only limited use of subsurface injection of liquid sludge for demonstration purposes or for emergency disposal of sour sludge. In the original plan, injection of sludge at rates up to 175 dry tons/ha [78 dry tons/acre] would have been used. At this rate, there is significant potential for groundwater contamination from salts, and nitrates. EPA will require as a grant condition that subsurface injection be limited to agronomic rates, based on the nutrient supply for the area. This will result in very little leaching of nitrates to the water table, as most will be utilized for plant growth. The rate of sludge application will be low enough that very little problem from salts reaching the groundwater should be encountered.

At the high application rates originally proposed, the fate of the soluble nitrogen forms in the soil is extremely important. The ammonia in sludge would be partially tied up on clay particles, making it available for longer periods of time to plant; but with dryland crops and some inhibitory effects, very little of the nitrogen would be used by crops. Gradually some of this nitrogen would be converted to the nitrate form and would migrate to the groundwater. Severe localized effects could be expected in groundwaters receiving the nitrate slug with the leachates. Because of this potential problem, the decision to limit subsurface injection to agronomic rates was made. This method of sludge utilization has shown promise in recent studies, and further study of its effects under carefully controlled conditions is warranted.

The only time subsurface injection of sludge will be used as a disposal method is if, inadvertantly, sour or malodorous sludge is sent to the site. This would prevent the sludge from ever being exposed to the air and creating odor problems. This event is expected to occur only rarely, if at all, as under normal circumstances sour or improperly digested sludge will be retained at the plant for correction of the problem and proper digestion before being sent to the site.

IMPACT OF SLUDGE DISPOSAL AT LOWRY BOMBING RANGE

The disposal of sludge to the Lowry Bombing Range represents the "no-action" alternative and would be continued if agricultural reuse of sludge is not implemented. Since sludge is currently being applied at a relatively high rate on the bombing range, this area provides the opportunity to assess the effects of sludge application. The Metro Denver Sewage Disposal District No. 1 is currently engaged in several research programs to determine some of these effects (Reference 114). Various types, rates and methods of sludge application are being used to measure the precise impacts. The results of Metro Denver's research project should provide quantitative data on high-rate sludge application at this site. The District's history of experience with land application of sludges, gained at the bombing range, will be a valuable asset in future reuse programs when the results are published. A summary of impacts of the present operation is graphically shown on Figure 18.

CONTOUR STRIP SLUDGE APPLICATION AT LOWRY

Food Chain

The entry of heavy metals into the food chain is a potentially adverse impact on areas of high-rate sludge application. Animals accumulate heavy metals not only from eating the plants, but also through direct ingestion of soil and sludge on the pasture areas. The composition and amount of sludge that is applied as well as soil conditions and plant characteristics are crucial factors in the availability of heavy metals. These relationships are discussed in detail in Appendix D. The Metro Denver research project should provide quantitative data on food chain parameters.

Of all the land application areas studied, the present operation at the Lowry Bombing Range comprises the greatest potential

FIGURE 18

SUMMARY IMPACTS OF SLUDGE DISPOSAL AT THE LOWRY BOMBING RANGE LANDSPREADING OPERATIONS

Impact parameter	Direction and intensity[a]
Food chain	●
Public health	•
Soil productivity	•
Soil salinity	●
Soil heavy metals	⬤
Water quality	●
Flora and fauna	•
Odor	•
Noise	•
Personnel effects	●
Plant operation and effluent quality	●
Aesthetics	•
Public reactions	•
Natural resources	○
Land use	•

[a] Symbols signify relative impacts, as defined below:

	High	Moderate	Low
Positive (beneficial) impacts:	◯	○	∘
Negative (adverse) impacts:	⬤	●	•

This schematic representation of impacts should only be interpreted within the context of analyses of impacts presented in the main body of the EIS. It is neither an attempt at quantifying the impacts nor reducing the diverse environmental parameter to common bases for comparison. However, it does provide a rough ranking of the relative importance of the various impacts.

hazard to the food chain with cattle, destined for the slaughterhouse and the grocery store, grazing unrestricted on sludge-amended areas. Overall, existing operations represent only a moderate adverse impact.

Public Health

In the past, no significant health problems have been associated with the Lowry Bombing Range sludge disposal operations. If these operations continue, it is expected that, under most conditions, the public health situation will not change. However, the relative longevity of pathogens in soil (especially enteric parasites and their eggs or cysts, such as *Ascaris* ova) and the daily proximity of workers and other project personnel with the sludge-loaded soil would continue to present a health hazard that must not be underestimated.

Effects on Personnel--

The present landspreading system in use at Lowry presents an operating hazard to workers on the site. The high concentration of lime used to disinfect the sludge makes the material to be applied very caustic (pH 11-12). Injuries to skin and eyes of workers have resulted on occasion. Application by truck of a semi-solid sludge also poses an operating hazard with the danger of overturning or losing control of the truck. With the advent of anaerobic digesters, the pH of the sludge would be nearer a neutral value (7) and would present less of a hazard to workers.

Plant Operation and Effluent Quality

If the present Lowry operation is continued, with the addition of anaerobic digesters, recycle of supernatant from the digesters is expected to have a negative impact on the Metro Central Treatment Plant (see discussion on page 124).

Soil Properties

As long as soil incorporation of sludges at the currently heavy rates are kept below the conservative guidelines (presented in Section IV under irrigated farms and in Appendix D), it is expected that soil conditions and properties at the Lowry Bombing Range disposal site will improve with increased fertilizer levels and organic matter. Obviously, nitrogen and other fertilizer components of the applied sludge will be far in excess of that needed for the weeds and grasses growing on the site. The organic matter content of soils will rise to about 1.75 percent in the top 15 cm (6 in.) of the soil, at the current 400 metric ton/ha [175 ton/ac] total loadings. This value will continue to rise as more sludge is added to the soil. This is a significant increase over the background levels of less than 0.5 percent. Thus, great immediate benefits to the soil structure, permeability, water availability, root penetration and erosion resistance will accrue.

The relatively high natural pH in these soils will help keep heavy metals concentrations from becoming toxic to plants and a threat to the food chain. The main difference between the bombing range condition and that of the irrigated farms is that the impact occurs over a much shorter period of time in the case of the bombing range. Thus, salt accumulation in the root zone will occur rather rapidly, especially with the low rainfall levels and lack of a significant additional water source limiting downward movement of soluble compounds. At current application rates, total soluble salt content of the soil plow layer will be increased to 0.2 percent of the soil mass, assuming that initial salt content is nearly nil. This level of salt concentration is not expected to cause more than a 30 percent plant yield reduction (Reference 115), given the existing vegetation. In fact, the yield reduction will probably be overshadowed by increases arising from enhanced fertility levels and soil conditions.

Water Quality

The Lowry Bombing Range sewage sludge disposal operations provide a unique opportunity for a quantitative assessment of impact of sludge reuse on water quality. Already, a network of catch basins, spring stations and monitoring wells have been established by the Metropolitan Denver Sewage Disposal District No. 1 in the immediate areas of past and present sludge disposal. Sampling and analysis of waters from these stations started in 1973 and are expected to continue on a regular basis for an indefinite period of time. The groundwater conditions are monitored through a large number of shallow and deep wells in the areas of soil incorporation of sludge. The cooperative program was started in late 1974 by the U.S. Geological Survey and Metro Denver District and is continuing at the present time.

Preliminary raw data from the surface water analyses are still not enough to help assess actual impacts. It can be surmised from the trends that nitrate nitrogen is already finding its way into surface waters and the shallower groundwater reservoirs. Individual catch basin concentrations of 29, 88 and 95 mg/l nitrate nitrogen (as NO_3^-) measured recently are alarming though not necessarily indicative of wholesale contamination. Most of the analyses indicate concentrations below 5 mg/l.

Preliminary data from the groundwater analyses show vertical nitrate migration in areas downstream of the older land disposal areas (8 to 44 mg/l NO_3-N) and in the vicinity of the landfill (13 to 23 mg/l NO_3-N). Although these are single-sample preliminary results they may indicate real trends. Despite certain doubts about the origin of the nitrogenous materials these trends may continue. Nitrate levels in groundwater could rise over the coming few years to levels above 45 mg/l (as NO_3^-), the limit at which their use for drinking water would be inadmissible.*

As expected, heavy metals concentrations have not yet increased in groundwaters, whereas preliminary measures in the topsoil have confirmed their accumulation. These metals are not expected to move downward in these calcareous, relatively high-pH soils. The continuing monitoring programs are an important advance warning system in this regard. The final report for the Lowry groundwater study is discussed in Volume II, Issue II-1.

Flora and Fauna

Vegetation--

Continuation of high-rate sludge application on the Lowry Bombing Range will cause similar impacts to the vegetation that can now be observed on that portion of the bombing range that has received sludge. This site is referred to as Site A and is shown in Figure E5. The sludge application process itself results in the complete displacement of the existing vegetation. However, no rare and endangered species have been reported on this site (Reference 34), and relictual mixed-prairie units, which are becoming scarce in the Denver area, do not occur at the disposal area. This conclusion was made from a field reconnaissance and should be verified by more thorough site surveys if land application is to continue. The original mixed-prairie unit has long been exposed to heavy grazing and presently contains many introduced annual grasses and annual and perennial weeds.

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*Recommended limit for nitrate nitrogen in domestic waters is 45 mg/l as NO_3^-.

The immediate impact of sludge application would be to stimulate the growth of weeds. The major weedy species found on Site A (common sunflower, Russian thistle, summer cypress and tumble pigweed) are fast-growing colonizers of bare soil whose growth has been enhanced by the nutrient value of the sludge. Over a long period of time, certain grass species would become established in the absence of grazing. Other management inputs, such as weed control and planting, would accelerate this process. As long as the site is grazed, however, cattle will selectively crop grasses and the weeds will continue to be dominant.

The establishment of a vegetative groundcover is essential to control soil erosion and surface runoff. Although grasses are superior to weeds in checking erosion, the dense weedy growth on Site A does serve to limit problems resulting from soil erosion and runoff.

Site A is being used for a research project by Metro Denver Sewage Disposal District No. 1 on the effects of high-rate sludge application on vegetation and cattle (Reference 114). Two major areas of concern are the high nitrate levels and the accumulation of heavy metals in plants and in the food chain. Many common weeds have high nutrient requirements (nitrogen, phosphorus and potassium) which limit to some extent the amount of nitrates that can be leached into the groundwater. Perennial grasses also have a high nitrogen requirement. The movement of heavy metals into plant tissue depends on many factors. The high phosphorus content of the sludge tends to make zinc, cadmium and nickel unavailable to plants. This property might be somewhat reduced by the calcareous nature of the soils. Calcareous soils have a high pH and tend to make phosphorus unavailable and immobile. Cadmium is potentially hazardous in the food chain, and its movement within the soil-plant system can be controlled by limiting the amount applied. In this way, excess zinc would injure the crop before the zinc or cadmium content of the crop constituted a health hazard (Reference 116). This relationship is explained more fully in Appendix D.

Seed germination is inhibited if planting operations are conducted too soon after the application of liquid sludge. If planting is done from two weeks to one month after sludge application, seeds germinate successfully.

The impacts of high-rate sludge application to this site will presumably be quantified when the Metro Denver research report is available.

Wildlife--

High-rate application of sludge upon the Lowry Bombing Range produces a distinctive plant community as described above. The resultant plant growth would exhibit a tendency towards a variety of herbaceous annuals. These fast-growing "weeds" can compete with the existing grasses and are often thick-stemmed, fibrous, and in some cases bearing thorns. They are generally less suitable than the short grasses for animal forage, but may be grazed upon in the tender stages or during periods of food scarcity. The ability of various plant species to accumulate sludge constituents, such as heavy metals, depends upon many factors as discussed in Appendix D. High concentrations of zinc, copper and cadmium in forage could have deleterious effects upon animals. However, severe toxicity injury from metals normally occurs in vegetation at lower concentrations than those toxic to animals. Some grazing animals, particularly sheep, are unusually sensitive to copper and could be injured by eating some forages enriched in copper by sludge. Few studies have been conducted on particular animal avoidance by taste or odor of vegetation grown on sludge (Reference 117). In general, when suitable grass forage is available, grazing animals will eschew the tough and unpalatable "weed" species. Cadmium and zinc are accumulated generally in the foliage and are found only in low concentrations in fruit, root and grain parts. Wild grains, seeds and fruit from grasses and "weeds", particularly sunflowers, would provide a satisfactory food supplement for seed-eating birds and small mammals. This would be particularly beneficial to wildlife in the fall and winter.

The shift in plant species would also result in a change in the microclimate on the surface and several centimeters below the surface. The broad-leafed herbaceous plants with relatively deeper root systems would contrast sharply with the groundhugging short grasses with shallow, fibrous root systems. The combination of reduced insolation and semi-moist organic material in the soil would lead to decreased surface and substratum temperatures with slight increases in humidity. This micro-environment may be particularly favorable to invertebrate species and may encourage the establishment of new species as well. The low-diversity and unbalanced plant ecosystem may also lead to the preponderance of only a few species.

High-rate sludge application and mixing into the upper soil zone would probably have the greatest direct effect upon burrowing and ground-dwelling rodents. Initial sludge application would temporarily destroy the uplands vegetation habitat and cause a displacement of local rodent populations to adjacent areas. With the re-establishment of vegetation and aging and maturation of the organic-laden soil, some rodents--such as pocket gophers and ground squirrels--may return to the area. Ground squirrels are generally seed-eating and use the underground burrows chiefly as retreat and nesting areas. Pocket gophers, on the other hand, reside almost exclusively underground, burrow continuously and feed upon subterranean root stocks and other material. The gopher may actually accumulate sludge constituents such as heavy metals through direct ingestion as well as digestion of plant material. A decrease in rodent numbers may not be significant to humans, but nevertheless is important to the ecosystem balance. Gopher populations within an area may have a contributing effect upon the food chain, as these small animals are preyed upon by hawks, eagles and coyotes.

Grazing animals may be exposed to pathogens and parasites by direct exposure and ingestion during feeding. Pathogens will be greatly reduced over time and by thorough incorporation. However, parasite ova such as *Ascaris* may remain viable over many years, potentially causing serious animal diseases.

The ecosystem shift and effects upon wildlife are localized to the sludge application areas and are generally short-term. Without further sludge applications, the altered vegetation community would gradually change to an upland vegetation unit in three to five years. With continuing periodic sludge application, this altered and unbalanced ecosystem could be perpetuated over the long term.

Large-scale sludge application at the Lowry Bombing Range may affect the habitat of the endangered black-footed ferret. If the project destroys any prairie dog towns on the site, it may affect the main food source of the black-footed ferret.

Noise

Continuation of the present landfilling and high-rate sludge application methods would perpetuate the existing noise levels from machinery and associated activities. As stated under the environmental setting, the climatological conditions and openness of the prairie would disperse sound well. In addition, the low population density and isolation from other noise sources make the noise contribution from the project almost insignificant.

Air Quality

The application of sludge to the bombing range should not adversely affect air quality if the sludge is promptly incorporated into the soil. The potential for particulate matter to rise and be dispersed exists if the sludge is stockpiled or not incorporated soon after optimum moisture condition is reached. Particulate matter can contain heavy metals and microorganisms that might be ingested by people. Lead, particularly, is a health hazard. When the sludge is well mixed in the soil, the potential for dust and particulate dispersal is reduced by the soil-binding character of the organic matter in sludge.

Odor--

The present operation's odor problems are not now serious and are not expected to be significant in the future. Under present operations, with largely undigested sludge, odors are easily perceived at close proximity to the application areas. The small amount of air-dried anaerobically digested sludge currently stockpiled is almost free from odors.

Aesthetics

Continuance of operations at Lowry Bombing Range would have no significant adverse aesthetic impact. The isolated area and neighboring landfill operations place the operation in an unobtrusive setting. Even at the close-range view, the application areas resemble newly-plowed fields.

SLUDGE ON LAND BEFORE PLOWING

Traffic and Circulation

Should the proposed project not be implemented, truck traffic to and from the Metro Denver Central Plant facility and the Lowry Bombing Range will continue at a rate of thirty-five to forty truck trips per day until such time as an alternate disposal method is adopted.

Public Reactions

Earlier adverse public reactions concerning Lowry operations resulted from system inadequacies which have since been remedied. The number and validity of the complaints about odor have been dealt with in the section devoted to that topic. Continued use of the Lowry site would probably result in continuance of these complaints. Complaints have averaged about one per month, with 80 percent found to be due to some other source, and the remaining 20 percent due to inclement weather or operations breakdown (Reference 39).

Natural Resources

The lands on the Lowry Bombing Range are currently utilized as range and pasturelands and, thus, this area exists as a grazing resource. As such, the potential for grazing has been reduced in areas of sludge application by the lack of range management practices that would ensure adequate forage species composition. Although these areas have been reseeded with wheat and forage grasses, the continuation of grazing combined with the absence of weed control has produced a site that is dominated by weeds and has marginal value as rangeland. Continuation of sludge application in the absence of sound range management techniques would thus constitute a reduction in the grazing natural resource.

High-rate sludge application could beneficially affect this natural resource if a weed control program was implemented and if the potential were recognized for hazardous heavy metals entering the food chain, and possible overloading of salts and nutrients in the soil.

The application of excessive amounts of sludge under a highreate application program constitutes a loss of nutrient resources.

Land Use

Should the proposed project not be implemented, the Lowry Bombing Range may continue to be the application site for Metro Denver sludge. There is evidence that heavy metals are building up in the soils as a direct result of intensive sludge application (Reference 118). This would reduce the types of uses which the disposal area could otherwise offer.

IMPACT OF SLUDGE LANDFILLING AT LOWRY LANDFILL

The landfilling practice near the Lowry Bombing Range is essentially a winter-weather and emergency practice which comprises a portion of the "no-action" alternative. During the winter, when it is difficult to perform the regular soil incorporation practices, sludge is dumped at high rates on prepared bench-and-terrace areas. Sludge is emptied from the backs of trucks to a depth of 60 cm [24 in.] and mixed at a 5:1 ratio with soil. This amounts to a loading rate of 670 dry metric tons/ha [300 dry tons/ac] per year. Winter landfilling during December, January and February has been practiced since 1971 but is expected to cease if the proposed agricultural reuse plan is implemented.

Soil Properties

Native soil is removed from the landfill areas prior to dumping sludge. The soil is stockpiled and used to mix with the sludge during dumping and for final cover. At the very high rates used, sludge components will saturate the cation exchange sites of the soil and increase its salt content, making it a practically unproductive material for crop production or pasture. The increased water-holding capacity caused by increased organic content will help delay leachate formation but will not prevent it in the long term. Overall, the impact upon the soil from landfilling will be destructive and extremely long lasting.

Water Quality

Nitrates and heavy metals will gradually be leached by percolating rain water and carried toward the groundwater reservoirs. Already, concentrations of nitrates in well waters in the vicinity of the landfill area are significantly above background levels; i.e., 13 to 23 mg/l in contrast to background levels of 0.01 mg/l or less. These trends are expected to continue unabated unless an impermeable layer is placed on top of the old fill areas and beneath the new ones.

It is expected that heavy metals will gradually move downward toward the water table from the landfill unless leachate-prevention mechanisms are implemented.

Surface water pollution from the landfilling operation is expected to be minimal because of the soil cover provisions and prior site preparations minimizing runoff from the sites.

Flora and Fauna

Vegetation--

The impacts of a landfill on vegetation are of a complete and long-term nature. Existing vegetation is removed with the excavation of trenches for sludge disposal. At the completion of disposal operations, the District plans to overlay the area with a topsoil material and revegetate with annual grasses. The success of the revegetation program depends primarily on such factors as soil conditions and management inputs, such as weed control. Grasses are generally tolerant of heavy metals in the soil, and the establishment of a permanent groundcover in this area would probably not encounter any severe problems. Heavy metals accumulating in plant tissues should be recognized as a reality, particularly if the site is to be grazed by livestock.

Wildlife--

Long-term disposal of sludge at the Lowry Bombing Range by landfilling would cause a definite change in the local plant community and a probable shift in wildlife species.

Landfilling, which would probably be a seasonal activity, involves complete destruction of the existing habitat by excavation, trenching, and deposition of sludge and placement of soil cover over the mound. Wildlife, particularly small mammals such as mice, ground squirrels and jackrabbits, would be displaced to adjoining areas, causing temporary population stresses. The completed landfill cover would be relatively barren because of poorer soil conditions, rapid runoff, poor water retention capability and greater exposure. This anomaly in the landscape would be difficult to incorporate into the upland vegetation habitat and is effectively lost to wildlife usage. Landfilling as a method of sludge disposal, however, does not disturb as great an area as does broad-scale surface application because the material is concentrated in a smaller area.

Air Quality

Because the landfilling operation is restricted to the winter season and adequate final cover is provided, no air pollution potential is expected from this operation. Safeguards against erosion and removal of the final cover are essential, to maintain the sludge under constant cover and to prevent it from drying and blowing in the wind.

Odor--

Similarly, if the final cover is maintained, no odors will emanate from the site. Otherwise, the landfill can be expected to produce disturbing odors, detected at considerable distances, as past experience with unauthorized dumping has indicated.

Explosive Gas Production

Solid waste landfills in general, and sludge landfills in particular, produce significant quantities of combustible gases such as methane during the process of anaerobic decomposition. When mixed with air (5 to 15 percent combustible gas in the mixture), they are explosive and can pose a safety hazard to humans in the vicinity. Special provisions for venting such gases are necessary.

Land Use

Whether the proposed project, i.e., beneficial agricultural reuse of sludge, is implemented or not, general uses of the Lowry landfill will be unchanged since the area will remain a disposal site for the Denver urban area.

Resources

Burying the sludge in a landfill constitutes wastage of a resource of potentially high fertilizer and soil-conditioner value. The extent of this loss can be visualized from the discussion of impacts of sludge application on the soil, discussed in this Section and in Appendix D.

Summary of Impacts of Sludge Disposal at the Lowry Bombing Range

As currently practiced, the land spreading operation at the Lowry site exerts the greatest negative impact on the food chain through pasturing of domestic animals on sludge-amended fields. Heavy metals accumulation in the soil, salinity of the soil and groundwater quality problems are other negative impacts of the current practices. Improved soil productivity and a partial conservation of natural resources are among the beneficial impacts of the present disposal operations. These impacts are schematically represented in Figure 18.

179.a

SECTION V

179-6

This section contains recommendations for possible modification of the original project proposal (or in the case of land application on reuse areas, additional controls that were not contemplated in the facilities plan) to reduce or eliminate environmental impacts. Negative impacts of major elements of the land application plan--processing, off-site application and the Lowry operation--are listed, and mitigative measures are recommended.

SECTION VI

NEGATIVE IMPACTS AND RECOMMENDED MITIGATIVE MEASURES

Key negative impacts identified and discussed in Section V are listed in this Section with possible mitigative measures which may be selected during the review process of this Draft EIS for final implementation. These tentative mitigation measures are recommendations by EPA and its consultant (Engineering-Science, Inc.) for consideration by the reviewing agencies and the public. Through the review process, acceptable effective measures will be selected from those presented here and those which may be offered by the reviewers of this document. The measures thus selected will become an integral part of the design and operation of the facilities planned by Metro before Step 3 grant monies are extended for the construction of the facilities. The final EIS will include the selected mitigation measures.

It is extremely important that whatever mitigative measures are adopted be integrated with the planned monitoring and surveillance activities so that symptoms detected by the monitoring system can lead directly into specific mitigative action.

PROCESSING, TRANSFER, DRYING AND DISTRIBUTION

Groundwater Pollution by Nitrates and Salts Leaching from Sludge Drying Basins

Lining the bottom and sides of basins with impermeable materials is the only fully effective way to mitigate nitrate and other salt accumulations in the groundwater. Nitrate movement can probably be slowed by maintaining anaerobic conditions in the bottom layer of the drying beds (this possibility has not been fully demonstrated as a guarantee against nitrate movement). Provision of drainage networks below the basins can be effective against nitrates and other salts but will not stop all leachates from moving to the water table. This method is more effective if an impervious layer is also installed. Furthermore, the collected drainage water must also somehow be safely disposed.

Return of the supernatant from the digesters to the treatment plant headworks (rather than pumping it along with the sludge to the sludge drying and distribution center) would be a great help in reducing salt pollution of the groundwater. Drying of the supernatant in separate, lined drying basins and containment of the dried salts would also be a suitable--though partial--alternative mitigation measure against alt buildup in the groundwater. A discussion of alternative types of liners is found in Volume II, Issue IV-2.

Surface Water Pollution from Experimental Plots

Impoundment of runoff water in reservoirs at the lowest parts of the center and treatment or proper disposal (e.g. irrigation of experimental plots and wetting the sludge stockpiles on windy occasions) of the waters gathered can adequately mitigate surface water pollution. This is part of the current site design.

Potential Threats to Public Health

Pathogen transmission through the air and through surface runoff waters and nitrate contamination of groundwaters are two main threats to public health which can be detected through continuous monitoring of pathogen longevity and groundwater quality under the drying and distribution site. Mitigation measures for public health hazards could include: (1) lining the drying basins with impermeable materials, (2) provision of special medical services for the employees at the center, (3) restriction of public access to the site, (4) maintenance of optimal digestion conditions in anaerobic digestors, (5) provision of special medical monitoring and preventive treatment to persons frequenting the site for taking delivery of sludge loads and (6) a strict ban against pumping of undigested sludge at all times.

Proliferation of Insect Vectors on Sludge Drying Basins

A qualified entomologist should be retained at the early stages of full utilization of the drying basins to identify specific insects colonizing the basins. Control measures defined through the identification process should be implemented.

Air Pollution from Particulate Matter of Sludge Origin

Sprinkling of the stockpile areas during windy periods and storage in gently sloping heaps (in contrast to high abrupt mounds) would help minimize dried sludge being blown in the wind. However, with above-ground storage it will not be possible to completely prevent loose material from being blown.

Production of Nuisance Odors in Drying Basins

Odors can be minimized with proper digestion of sludge and maintenance of an adequate buffer zone between the basins and site boundaries. Odor production on the site itself cannot be wholly prevented.

Negative Public Reaction to Establishment of the Drying and Distribution Center

A proper public education campaign with full disclosure of all environmental, economic, political and social considerations involved with the project should provide a healthy atmosphere of open dialogue. This will help improve the acceptability of the drying and distribution center to the neighboring farming community.

LAND APPLICATION IN SLUDGE RECYCLING AREAS

Lands which will be the ultimate repositories of dried sludge will be the most critical impact areas in the sludge handling process. This is due to the fact that many of the impacts discussed are of a cumulative, long-term nature. Therefore, mitigative measures are essential for success of the beneficial reuse scheme. EPA will require that sludge be retained onsite until state regulations on sludge management are finalized.

Heavy Metals Accumulation in Soil, Plants, Animals and the Food Chain

(1) Removal or reduction of sources contributing heavy metals to the wastewater management system will mitigate many of the adverse impacts on soils, plants, animals and the food chain. This can be done by enforcement of the existing wastewater ordinance, setting tolerable limits on concentrations of exotic substances entering the sewer system, thus forcing industries to adopt in-plant measures to curb discharge of heavy metals.

Exclusion of industrial and other heavy metal discharges from the wastewater treatment system will allow prolonged use of sludge on the various sites.

(2) Control of cadmium:zinc ratio is another important mitigative measure. If this ratio is kept below one percent, acceptability of sludge for use on feed crops and foods will be greatly enhanced through the plant yield reduction effected by zinc, long before either element accumulates in toxic concentrations.

(3) Record-keeping, inspection of sludge application operations on individual sites and monitoring of environmental parameters are functions which must be carried out by the District or another responsible agency in close cooperation with individual farmers and oper-

ators. These functions will prevent inadvertent aggravation of impacts by excessive, non-uniform or careless applications of sludge and will mitigate the adverse impacts. It may be necessary to obtain binding agreements with recipients of sludge to permit inspection and monitoring and to provide for cessation of sludge supply in cases of noncompliance with recommended management practices.

(4) In many cases, it may be necessary to subsoil the farmland prior to or during the first sludge application pass, in order to bring to the surface some of the calcareous material in the lower soil horizons. Alternatively, lime amendment would also help increase soil pH, if necessary. This will help hasten the "reversion" of heavy metal elements to unavailable forms.

(5) Crop selection to favor non-foliar edible parts and younger rather than older plant parts can help reduce magnification of cadmium and other heavy metals in the food chain.

(6) Surface spraying of liquid sludge should be avoided, especially on pasture areas where it may be directly injected by livestock.

(7) If research indicates that it is warranted, exclusion, at the slaughterhouse, of kidneys and livers from the meat of animals having grazed on--or having been fed hay and other feeds raised on--sludge-amended farms and the disposal of these organs at a sanitary landfill would be an excellent mitigation measure. The ability of these organs to concentrate heavy metals would thus be beneficially used as a device to eliminate them from the food chain.

(8) Restrictions or discouraging use of sludge on home gardens, especially where leafy vegetables are grown.

LIVESTOCK GRAZING ON SLUDGE-AMENDED FIELD

Nitrate Pollution of Groundwater, Especially in Irrigated Farms, Sod Farms, Home Gardens, City Parks

While the active process of leaching of nitrates into the groundwater table cannot be avoided, the extent and duration can be substantially reduced. Periodic monitoring should be conducted on groundwater assoicated with each site that is receiving sludge. Before nitrate concentrations reach 45 mg/l N as NO_3, usage of sludge should be curtailed, and the groundwater should be restricted from potable use. Such a measure would be most appropriate in the vicinity of shallow groundwater supplies used for domestic purposes.

Nitrate Pollution and Eutrophication of Lakes and Other Water Bodies

(1) The pollution of surface waters can be mitigated by strict control over application rates so that a balance between nitrogen uptake by plants and available nitrogen content of sludge is adhered to as closely as possible. Water quality should be monitored to detect any buildup of nitrates.

(2) Control of the tailwater in irrigation systems and use of standard runoff and erosion control practices on the farm can reduce the threat of surface water pollution.

(3) Riverbeds, flood plains and steep slopes should be categorically excluded from sludge application, unless positive tailwater control is included.

(4) Careful watering practices by users should include insuring that surface runoff does not occur.

Air Pollution from Particulate Matter of Sludge Origin

Particulate matter from dried sludge applied to soils can be reduced by several means: (1) deep incorporation of sludge into the soil by mechanical means as soon as possible after application; (2) subsequent irrigation to keep particulate matter in the soil; (3) appropriate scheduling to avoid or minimize sludge application during windy conditions--particularly in the springtime; (4) opportunistic timing to apply sludge immediately prior to forecasted rainstorms and; (5) injection of liquid sludge deep below the surface wherever this is a feasible practice.

Exposure of Humans to Viable Pathogens and Parasites

(1) The use of sludge which has been air-dried for at least two years would greatly reduce the numbers of viable pathogens. Addit-

ional methods of pathogen reduction in sludge include: (a) pasteurization for 30 minutes at 70°C [158°F]; (b) high pH treatment, typically with lime, at a pH greater than 12 for three hours; (c) long-term storage of liquid digested sludge (if applicable) for 60 days at 20°C [68°F] or 120 days at 4°C [40°F]; (d) complete composting at temperatures above 55°C [131°F] for at least 30 days; (e) use of chlorine or other chemicals to stabilize and disinfect sludge. Current research shows preliminary promise in the use of high energy electrons for disinfection of sludge passing in a thin stream in a specially adapted process. The feasibility of use of these and other means of pathogen destruction should be continually considered for application and use.

(2) The possible introduction of pathogens into surface waters will be mitigated if sludge is not applied in the close vicinity of lakes and other water bodies.

(3) Soil and water monitoring for pathogens should be regularly conducted.

(4) Use of sludge on vegetable crops (such as in home gardens) and all foods eaten raw should be strictly banned. EPA guidelines suggest a three-year waiting period prior to using sludge-treated land for food crops to be eaten raw by humans.

(5) Use of sludge on parklands should be controlled to avoid areas where humans could come in contact (e.g. grass areas) and limited to areas where control can be maintained (new sod, flower gardens). Sludge applications should also be limited to times of the year when chance of exposure is slight.

Exposure of Animals to Viable Pathogens and Parasites

Mitigative measures such as those enumerated above, under Exposure of Humans to Viable Pathogens and Parasites, are equally effective in protecting domestic animals and wildlife from adverse effects of sludge pathogens and parasites.

Odor

Proper timing of sludge application will mitigate odor impacts. Further mitigation measures applicable to odor are discussed above, under Air Pollution from Particulate Matter of Sludge Origin.

Adverse Public Reactions

The promotion of a public education program to inform the public of the benefits and potential effects of sludge application will almost certainly increase acceptability of the concept and its widespread adoption in the farming community.

Initial Toxicity of Liquid Sludge to Seeds and Young Plants

Where liquid sludge is applied on irrigated or non-irrigated farms, mitigation would consist of a delay of planting until one month after application.

Injection of Sludge From Foilage and Soil

(1) Spraying of sludge on growing crops and pastures should be avoided;

(2) Cattle should not be pastured on land having received sludge recently;

(3) Sludge should be incorporated into the soil as soon as possible;

(4) Use of deep liquid sludge injectors should be encouraged, particularly on dryland farms and pastures.

EXISTING DISPOSAL OPERATIONS ("NO ACTION") AT LOWRY BOMBING RANGE

Heavy Metals Accumulation in Soil, Plants, Animals and the Food Chain

This impact could be particularly severe in areas where livestock grazing is conducted. It is somewhat mitigated by the limitation of total application rates. However, the high time rate of application causes uneven incorporation and high local concentrations, posing hazards to the food chain. Should it be demonstrated that grazing in sludge application areas, results in high organ metal concentrations, then livestock should be prohibited from grazing on sludge-amended fields. For mitigation measures, refer to page 183.

Possible Loss of Unique Vegetation Type

The location of any relictual mixed-prairie units should be verified by a thorough site survey. Loss of any existing examples of this type would be mitigated by the exclusion of these areas from future sludge application sites.

Possible Destruction of Rare and Endangered Plant Species

The occurrence of any rare and endangered plant species should be verified by a thorough site survey. Destruction of these plants would be mitigated by avoiding areas where they may be found. Appropriate botanical authorities should be notified of the location of rare or endangered plants.

Possible Loss of Black-Footed Ferret Habitat

The location of any prairie-dog towns should be noted, and a thorough site survey conducted to determine concurrent habitat association for the endangered black-footed ferret. If the black-footed ferret is found on the site, its habitat should not be used for sludge application.

Air Pollution from Particulate Matter of Sludge Origin

Mitigative measures are discussed above, under Sludge Recycling Areas.

Reduction of Grazing Resource

The implementation of range management practices, such as weed control and the exclusion of livestock from treated areas until a forage crop is well established, will mitigate this impact.

LOWRY LANDFILL

Removal of Wildlife Habitat

A rigorous attempt at revegetation of the final cover over the landfill area will help restore the habitat to some extent.

Groundwater Pollution

Unless the bottoms of new fill areas and the surfaces of old areas are covered with impermeable materials such as liners or clay layers, groundwater will be polluted with nitrates, salts, carbon dioxide gas and perhaps even heavy metals over long periods of time.

Explosive Gas Production

Use of venting systems, standard on sanitary landfills, can prevent accumulation of explosive concentrations of combustible gases generated in the sludge fill area. Such systems are not now in place at the Lowry landfill.

SECTION VII

The long-term implications of the Metro proposal and the continued use of the Lowry system are reviewed in this Section. First, those impacts of an adverse kind that cannot be avoided--even with the use of mitigating measures proposed in Section VI--are described. Next, consideration is given to the irreversible commitments of resource use that will occur with this proposal or with the existing system. Finally, an evaluation of overall productivity in the long run is presented.

SECTION VII

LONG-TERM CONSIDERATIONS

Major projects such as the large-scale reuse of sludge on the land have long-term implications which are often different from (and sometimes far more significant to environmental parameters than) those initially envisaged.

The state of knowledge on precise impacts of sludge reuse on land is in the state of infancy. Thus it is relatively difficult to determine accurately the short-term effects (such as water pollution, public health hazards, air pollution, food chain disorders, etc.). There is even less basis for quantifying long-term effects, which may be far more pernicious and pervasive than short-term impacts, as a whole. By the same token, the beneficial long-term effects that can now be described only generally and qualitatively may in time prove to have been totally underestimated or grossly exaggerated.

The very unknown nature of future cumulative impacts should be ample warning to proceed with caution, to use sludge on lands where known impacts are minimal (such as sod farms, mine spoil sites and dry farms) and to avoid those where we now know the impacts can be significant (such as home gardens and farms growing crops consumed directly). The transitional state of knowledge about sludge reuse impacts also makes it extremely important that the planned and necessary additional monitoring activities on all environmental parameters be implemented rigorously and diligently to provide early warnings of hazardous conditions which may be developing.

ADVERSE IMPACTS THAT CANNOT BE AVOIDED

Sludge Drying and Distribution Site

Disturbance of 240 Hectares [600 Acres] of Soil--

The destruction of soil profile to create the drying basins cannot be mitigated. Once the natural soil strata are destroyed, they cannot be exactly reconstituted, nor can they be restored to those that were formed under natural soil-forming conditions over geological time. Long-term reclamation including the use of sludge, could restore some or all of the former productivity of the land. The nature of the subsoil material will, to a great extent, determine the potential for rehabilitation.

Salt Movement Toward Groundwater Table--

Up to 190 metric tons [210 tons] of salts will leach each year from beneath the sludge drying basins under present design conditions.

Nitrate Pollution of the Groundwater Reservoir--

Unless further research and possible procedural adaptations can assure complete denitrification at the bottom of the drying basins, pollution of the groundwater by nitrates leaching from the sludge drying basins will be unavoidable under present design conditions.

Land Application Sites for Recycling Sludge

Salt Accumulation in the Region--

The soluble salts in the sludge constitute a cumulative, conservative (i.e. not subject to breakdown) pollution of the soils and waters of the whole region. Their dispersal over a very large area, as expected in the agricultural scheme, only delays the time at which their increasing regional concentration will become perceptible. The time frame for such accumulation will probably be a few hundred years.

Exposure of Burrowing Animals to Pathogens and Toxic Elements--

No effective long-term mitigation measures exist to prevent burrowing animals from possible exposure to pathogens and trace elements by ingestion or direct contact.

Mismanagement and Consequent Unmitigated Adverse Effects--

Under present plants, no firm controls on the ultimate users of the sludge are envisioned. The possibility is very real that some of the recipients will fail to include recommended mitigative measures in their sludge use activities. This could result in the negative impacts enumerated in Section VI, under Land Application in Sludge Recycling Areas, to become threats to the region.

Lowry Bombing Range Sludge Disposal Area (No Action)

Salt Accumulation in Soils--

No mitigation measures exist for the addition and accumulation of inorganic salts in the soils under present applications rates and conditions.

Nitrate Pollution of Groundwater--

At the current very high annual application rates, far more nitrogen is introduced into the soil than can be utilized by the plants. The balance is partly denitrified and partly leached--with the occasional rainwaters--below the root zone and toward the groundwater table. The impact upon groundwater quality will not be evident for many decades because of the very slow rates of unsaturated flow of water. But eventually, perhaps in 50 to 100 years, impacts will begin to appear. It will then take many more decades to reverse the trend.

Ingestion and Direct Contact with Sludge by Burrowing Animals--

No effective long-term mitigation measures exist to protect burrowing animals from the possible exposure and accumulation of sludge constituents by ingestion or direct contact.

Exposure of Domestic Grazing Animals to Heavy Metals Accumulation, Viable Pathogens and Parasites--

Under present practices, domestic livestock graze the sludge-amended fields without restriction, ingesting sludge along with soil particles which comprise about ten percent of their regular diet. To the extent that the "no-action" alternative implies continuation of this and other existing practices, endangerment of animal health and the subsequent food chain impact are a potential hazard.

Waste of Nutrient Resources--

No mitigation measures exist for the loss of nutrient resources under a high-annual-rate sludge application program, or when sludge is landfilled under emergency circumstances.

IRREVERSIBLE AND IRRETRIEVABLE RESOURCE COMMITMENTS

Four main resource commitments are involved in the proposed project:

Destruction of Soil Profile

Destruction of the soil profile on 240 hectares [600 acres] of land at the site of the proposed drying basins is irreversible. These areas would be unfavorably altered as agricultural areas with their characteristic soils.

Energy Use

Commitment of fossil fuels to produce energy for treatment, pipe transport, trucking and other sludge handling processes is necessary and irretrievable. The total value of this commitment for the proposed action has been estimated to be about eight million KWH per year. However, it is estimated that total savings in energy use accomplished by implementing alternative 2 (compared with the "no-action" alternative) amount to at least 28 million KWH per year.

Groundwater Use as Receiving Medium

Commitment of the groundwater reservoir as final repository of soluble salts and nitrates leached from the applied sludge is implicit under present design conditions for the sludge drying and distribution center. Over several centuries, salt accumulations in the groundwaters will gradually become increasingly appreciable. It is a slow but inevitable process that can only be corrected by nature over a similar length of time after cessation of land application operations.

Application Site Soil Commitment

Commitment of the soil root zone as a final repository of heavy metals (and in some locations soluble salts) in the sludge is inevitable as long as sludges continue to contain these materials. This allocation of the soil resource is irreversible in the sense that upon completion of the land application it will take many centuries of continuous cropping to remove the heavy metals, through gradual uptake, from the soil.

RELATIONSHIP BETWEEN SHORT-TERM USES OF THE HUMAN ENVIRONMENT AND THE MAINTENANCE AND ENHANCEMENT OF LONG-TERM PRODUCTIVITY

The land recycling proposal by Metro will probably have a duration of 25 to 50 years. This is a rather long period of time, given the rapidity of change in today's society. Nevertheless, it is a fair and important question to ask what the implications of the project may be for the next few hundred years--with regard to the soils, the water and other areas of human environmental concern.

Conservation of Non-Renewable and Renewable Resources

Such an evaluation can begin with the baseline of how the proposed system compares with the existing Metro sludge handling and disposal system. At present, high doses of lime, ferric chloride and polymers are necessary to obtain a dry enough sludge for truck hauling. Furthermore, the dewatering and trucking operations are fairly energy-intensive, requiring the use of electricity and fossil fuels.

The Metro proposal represents a positive step in conserving natural resources by eliminating the need for chemicals. Over a 50-year period, more than 200,000 metric tons [220,000 tons] of ferric chloride and 450,000 metric tons [500,000 tons] of lime could be conserved, along with a smaller tonnage of complex fossil-based polymers. These are chemicals that have little or no value to Denver area soils or in the landfills.

Overall, there is a net energy saving with the Metro proposal of at least 8 million KWH per year. While this overall amount represents a small fraction of the total energy used in the Denver metropolitan area, it nonetheless represents a significant step toward an energy efficiency and conservation ethic in wastewater management. The chief purpose of chemicals and energy in inputs to the sludge handling process is stabilization and drying of the sludge. In the proposed system, anaerobic digestion is used in lieu of chemicals and energy to stabilize the material; the proposed air-drying process represents a shift toward the use of solar energy in the drying basins, replacing mechanical dewatering systems, which require much energy derived from use of non-renewable fossil fuels. Solar energy is an inexhaustible replacement for these rapidly diminishing fossil fuels.

In the long term, the recycling of nutrients to the soil represents a forward-looking step for a society that will have to recognize the finite limitations of its natural resources. At present the bulk of our commercial fertilizers is produced from fossil fuels, particularly natural gas. While future sources of fertilzer (especially nitrogen fertilizers) will probably include coal, this, too, is a fossil fuel which has its limits. If nitrogen that has already been fixed (that is, made chemically reactive, as is the case with amino acids, proteins, nitrates, ammonia, etc. found in sludge) is reused, society will be able to make much further use of the resources for which there are no substitutes.

At present, the primary source of phosphorus fertilizer is deposits of phosphate that are extremely limited. Because phosphates in wastewaters are concentrated in sludge as a result of the treatment process, land recycling can be an important long-term mechanism for reuse of this element, providing soils with one of the macronutrients essential for crop production.

A third long-term benefit of land application of sludge from the Metro system is its effect on soil structure. Sludge contains large amounts of organic matter; in semi-arid areas of the western United States, where soils are poorly developed and are high in clay content, the addition of organic matter to the soil mass improves the friability of the soil and increases its water-retention capability. Ultimately the soil becomes more porous and allows greater root penetration. Agricultural experts usually warn against depletion of the organic matter in soils through exclusive use of commercial fertilizers. The Metro project could reverse this trend by recycling carbonaceous matter to the soil.

Potential Cumulative Long-Term Environmental Damage

A long-term view of the Metro proposal must include potential harmful effects. Because sludge contains elements that may be toxic or that may occur in combinations that are harmful, the potential exists for some long-term damage to the productivity of soils for growing crops.

Many of the trace elements of concern (zinc, copper, iron, etc.) are micronutrients when found within appropriate ranges of available concentration in the soil. It is their availability in excessive quantities that can produce toxic or inhibiting effects on plants. Growing plants continually remove small quantities of these elements from the soil as they are cropped, but this removal rate is far too slow to be expected to remedy the effects of rapid additions of the elements through sludge application--until centuries after application has ceased.

Another undesirable aspect of sludge application is the addition of salts to the soil profile. Over a long period of time, salts can have an inhibitory effect on plant growth. This problem is not confined to the Metro sludge operation but is common to all irrigated agriculture. Increased salinity of soils has an extremely harmful effect on the food-producing capability of a region. It is generally recognized in irrigated agriculture that proper long-term maintenance of an irrigated soil includes a leaching requirement, for flushing these salts below the root zone. This is accomplished through application of additional irrigation water, which commonly is subsequently collected in subsurface drains. While potential soil salinity can be remedied by leaching and drainage in irrigated agriculture, its occurrence on nonirrigated farms as a result of sludge addition would be inevitable.

Salts can also become contaminants of the groundwater resource. On any given sludge application area, the total annual salt load from applied sludge will be fairly small. It is at the sludge drying and distribution center that the greatest potential for effects on groundwater can occur, hence the need for lined basins and other mitigative measures.

The chief measure for avoiding the detrimental long-term effects of soil salinization and heavy metal accumulation is limitation of the amount of sludge applied to any one area to what is considered safe for that type of soil and land use. Recommended safe levels are still somewhat tentative; any long-term assessment of this project must recognize that some effects may conceivably occur in a manner different from that stated here. However, assuming that no change in sludge heavy metal content will occur, there is nothing at present to indicate that any completely irreversible damaging effects on productivity of the soil, through the proposed sludge application system, might occur.

What is most critically needed for the future is a research program to find out what can and will happen on various soils with applications of sludge. Maximum allowable heavy metal loading rates (hence sludge application limits) may have to be adjusted downward or upward as experience with actual sludge application becomes available. EPA feels that the limits so far recommended represent a conservative approach to protection of the soil.

The Long-Term Environmental Perspective

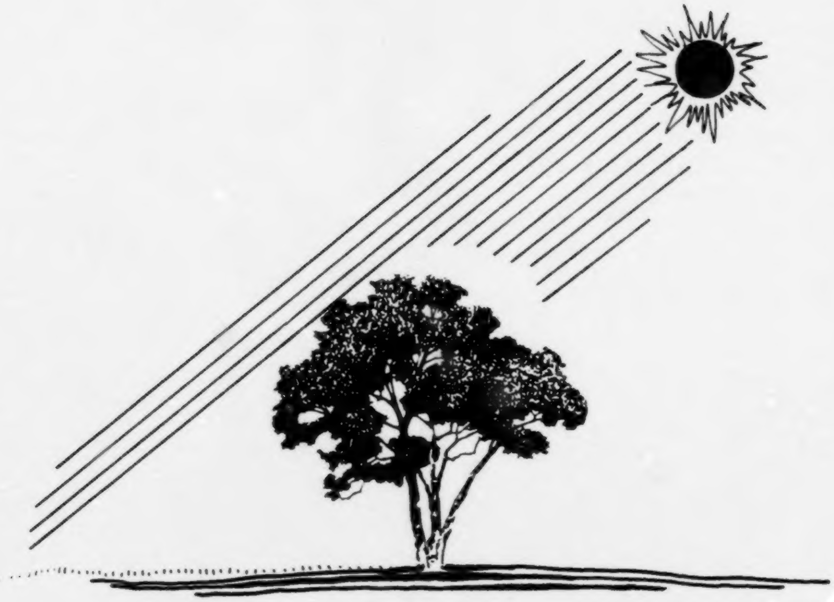
EPA feels that, viewed from an overall perspective, this project can put into action the goals of the National Environmental Policy Act. Although that part of NEPA requiring environmental impact statements has received the greatest attention, it should be remembered that the basic intent of NEPA is a national environmental policy integrating the actions of people with their environment. One item in particular stands out in articulating this policy in the Act which the proposed project can help achieve:

> *10(b)(6)*...[to] ***enhance the quality of renewable resources and approach the maximum attainable recycling of depletable resources.***

The extent to which the proposed project can increase use of renewable resources (such as nutrients, organic matter and solar energy) while decreasing dependence on nonrenewable chemicals and fossil fuels is considerable. If the additional measures recommended to protect against untoward effects (such as groundwater contamination and heavy metal accumulations) are included, EPA believes that this project can become a valuable pioneering effort toward building a society in which recycling and resource conservation are a way of life.

. . . *It is gilded wheat,*
it is bread on your table,
it is warm blood in your veins,
it is health,
it is joy,
it is life!

SECTION VIII



An important provision of the National Environmental Policy Act is that during the EIS process responsible public agencies and the public must be provided ample opportunity to participate and make contribution to the EIS. This Section is a brief report of the extent and nature of such involvement in the process of preparation of the EIS. Discussions and letters from citizens and Federal, State and local agencies in response to the Draft EIS are contained in Volume II.

SECTION VIII

COORDINATION WITH AGENCIES AND PUBLIC INVOLVEMENT

GOVERNMENTAL AGENCIES

During preparation of this Draft EIS, regular contact was maintained with the various public agencies charged with responsibilities for the environment, waste management, public health, food safety, water supplies, agricultural production, soil conservation and other public concerns related to the project. Among the agencies whose recent, current and planned activities were monitored in relation to sludge management are:

Various internal EPA units
Metro Denver Sewage Disposal District No. 1
Denver Regional Council of Governments
Colorado Department of Health
Adams County Commissioners
USDA Soil Conservation Service
U.S. Food and Drug Administration
U.S. Bureau of Reclamation

The Preliminary Draft EIS, prepared by Engineering-Science, Inc. in November, 1975 was reviewed by the EPA and local agencies directly involved with the proposed project. The comments received from their review have been of value in upgrading the present Draft EIS.

PUBLIC INVOLVEMENT

The proposed Metro Denver sludge management program has elicited significant public reaction. Some of the reaction was solicited by the District through public meetings and formation of a Citizens' Advisory Committee, formed in 1972, consisting primarily of representatives of interested agencies. Interested groups and property owners near the proposed site were also represented. The members of the committee were:

Beverly Fleming	Keep Colorado Beautiful (Chairwoman)
Gary Eaton	Adams County Engineering
Bob Fleming	Adams County Planning
Alan Foster	Denver Regional Council of Governments

Jim Fowler	Sierra Club, Enos Mills Group, Denver
William Gahr	Colorado Department of Health, Engineering and Sanitation Division
Mike Gansecki	U.S. Environmental Protection Agency
Jack Haines	Adams County
Richard Heaton	Denver Water Board
Bernard Korbitz	Presbyterian Medical Center, Department of Medicine
Glenn Kreag	CSU Extension Service, Adams County
Fred Matter	Colorado Department of Health, Water Quality Control Division
Rodney Preator	Soil Conservation Service
Elizabeth Richardson	League of Women Voters
Steve Rohlf	City of Commerce City
Robert Sandquist	Adams County
Calvin Tupps	Property owner in proposed project area
Wayland Walker	City and County of Denver Planning Office
Bob Wardell	CSU Extension Service, Adams County
Ann Ziegler	Property owner in proposed project area
Bob Ziegler	Property owner in proposed project area

While the reactions of environmentalists and public agencies were generally favorable, the public meetings with citizens of rural Adams County showed a strong resistance to locating the site in their vicinity. Earlier plans to locate District facilities in Weld County had met with similar resistance. The 1972 meeting in Bennett--a small town in eastern Adams County--drew about 80 persons. The strongest opinions of those attending the Bennett meeting were the following (Reference 8):

(1) The sludge application site should not be located in Adams County.

(2) More experimentation should be conducted before committing a large land area to sludge application.

(3) The consensus was that sludge application was not appropriate for dryland wheat farming.

(4) Subsurface injection of sludge would be preferred rather than spraying or other means of spreading on top of the ground.

A petition was submitted at this meeting opposing location of the sludge application in Adams County.

Following the Bennett meeting and a follow-up meeting at the Adams County Fairgrounds, and on the advice of the Citizens' Advisory Committee, the project was modified to overcome several of the most serious objections. The revised project was presented in the March 1974 report "Agricultural Reuse Program" (Reference 5). Citizens and Commissioners of Adams County, however, still expressed opposition to locating the project in Adams County. At the four public meetings in 1974, concerns were again expressed about possible condemnation of the land required for the site, potential odor problems, the feasibility of marketing the sludge, land devaluation and the visual aspects of the facilities. The major outcome of this public involvement in the project was its influence on the site selection study. The relatively isolated site finally selected (site B-2 shown in Figure 2) was recommended in large part to minimize adverse socio-economic impacts and public opposition.

In summary, public involvement in the project since 1972 has included seven sessions of the citizens' Advisory Committee and seven well-attended public meetings (with 75 participants). Persons attending the public meetings were antagonistic towards having the proposed project located near them in Adams County. The substantive issues brought up (odors, public health hazards, water quality impacts, etc.) are treated elsewhere in this report. Viewed simply from the point of view of public opinion indices, the meetings display a negative view of public opinion toward the project. However, these views may be unrepresentative since those believed to have objections to the project were contacted for the public meetings, and the meetings were held near the areas of greatest opposition to the project.

A meeting held with the Adams County Commissioners as part of the EIS process (Reference 83) showed that the Commissioners generally reflected the views of their constituents at the public meetings. While they were not opposed to the proposed project in principle, they wished to be more fully assured that potential environmental degradation had been adequately studied, that Metro Denver was not going to exploit Adams County and that the citizens of Adams County were not being treated in a high-handed or arbitrary manner.

Environmentalist groups have been in favor of the proposed project, generally viewing it as a beneficial reuse of a resource. It has also been favorably received by the general public (since except in the case of a very few people, the project is located near someone else).

Recent contacts with concerned parties have shown that the general attitudes described above are still prevalent at the time of this study. The farmers of Adams County have on the whole remained opposed to the proposed project (References 84, 70).

Some farmers within a 32-km [20-mile] radius of the drying sites have expressed a desire to use the dried sludge (References 85, 86).

Some have told the District that they are interested in using the sludge but prefer anonymity because the project is so controversial in this area. A sampling of some of the favorable responses from more distant areas is given in Appendix F.

Public Reaction to Drying and Distribution Site

The future project implementation in the area of the drying and distribution site will probably produce significantly adverse public reactions. One part of this expected impact is due to the rural/urban difference between the sludge-generating and sludge-receiving areas. If the residents of Adams County feel powerless to prevent, and are unwilling to accept, the project proposed by the more populous region to the west, public resentment will be inevitable.

A second reason to expect adverse reactions is the history of such reactions to Metro Denver in Adams County. Opposition appears to have hardened after years of altercations. Much of this opposition is perhaps inevitable with projects of this sort: however, even many sympathetic to the project have said that in the past Metro Denver public relations programs have left much to be desired (Reference 39). It will be difficult though not impossible to reverse this unfavorable image. The litigation between Metro Denver and Adams County concerning jurisdiction over the proposed project will probably not improve relations, regardless of its eventual outcome. Future litigation over condemnation of land and rights-of-way would be probable (Reference 113).

Public Reaction to Land Application Sites

While a generally unfavorable reaction toward the project can be expected, at least initially, adverse reactions against particular users of the dried sludge are not expected. A typical example of the reasons for this can be seen in the case of a representative farm studied east of Platteville (Reference 85) in Weld County. The farmer involved is interested in using the dried sludge from Metro and does not expect any problem with his neighbors. His farm is large--as are most farms in this general area--and the relative remoteness from the public makes nuisance conditions unlikely. This particular farmer has had experience with similar uses of sludge in Denver on lawns (about 30 years ago) and therefore sees no problem with using it now. He thinks that odors are not a problem and that some neighboring farmers are using smellier materials on their own land right now (e.g., heat-treated chicken manure from a nearby chicken farm). Such manure applications are considered an accepted part of farming operations. Finally, he has farmed his land for 30 years and is confident that other farmers will generally respect his right to conduct his operation as he judges best.

SECTION IX

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SECTION IX

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This Appendix contains the cost, engineering and environmental evaluations of basic process alternatives for sludge handling and disposal by EPA's consultant--Engineering-Science, Inc. (ES). ES concludes that the "apparent best alternative" is the system proposed by the Metro District. The Appendix also contains a detailed description of each alternative considered. Process flow diagrams, with sludge quantities passing through the process train, are presented. Pertinent assumptions in design and cost calculations are listed.

APPENDIX A

EVALUATION OF ALTERNATIVE SLUDGE HANDLING AND DISPOSAL SYSTEMS

INTRODUCTION

In the course of its efforts to improve its sewage sludge management practices, Metropolitan Denver Sewage Disposal District No. 1 retained an engineering consultant (CH2M Hill) to study alternative sludge processing and disposal systems and to recommend the best alternative. The results of the consultant's work are contained in a four-volume report, Volume II of which is entitled "Alternative Systems" (Reference 6).

Part of the present study involves an independent evaluation of the alternatives considered by the consultant, together with others, prior to assessment of the environmental impacts associated with the more promising alternatives. The material contained in this section summarizes the results of this independent evaluation. A more detailed description of the alternatives, with flow process diagrams, and their associated costs is included at the end of this appendix.

SYNTHESIS OF ALTERNATIVES

In order to compare alternatives in an equitable manner, the basic principle that each system must be complete in itself was adhered to. Thus, the complete system must take as its starting point the raw and digested sludges at the Central Plant, and as its end a disposal mode that is truly final; that is, a disposal mode requiring no further action to process or transport the sludge.

ALTERNATIVE SYSTEMS

Sixteen alternative systems were considered, eight of them similar to those evaluated and reported by CH2M-Hill. For convenience, the numbering system used in the consultant's report has been retained. Thus, Alternatives 1A through 8 are those evaluated by CH2M-Hill.

Alternative 1A	Existing system, waste-activated and other sludges trucked to Lowry Bombing Range for landspreading

Alternative 1B	Existing system with anaerobic digestion
Alternative 2	Anaerobic digestion, pipeline transport, air drying and beneficial reuse (product: 100 percent air-dried sludge)
Alternative 3	Filter presses, incineration, landfill of ash
Alternative 4	Heat treatment, vacuum filtration, landfill
Alternative 5	Heat treatment, air drying, landfill
Alternative 6	Heat treatment, vacuum filtration, incineration, landfill of ash
Alternative 7	Anaerobic digestion, filter presses, compost (product: 100 percent nutrient-enriched composted sludge)
Alternative 8	Filter presses, compost (product: 100 percent nutrient-enriched composted sludge)
Alternative 9	Anaerobic digestion, centrifugation, compost (product: 100 percent nutrient-enriched composted sludge)
Alternative 10	Anaerobic digestion, pipeline transport, air drying, compost (product: 50 percent air-dried sludge; 50 percent nutrient-enriched composted sludge)
Alternative 11	Anaerobic digestion, centrifugation, landfill
Alternative 12	Anaerobic digestion, pipeline transport, air drying, landfill, compost (product: 33 percent air-dried sludge; 33 percent nutrient-enriched composted sludge; remainder to landfill)
Alternative 13	Anaerobic digestion, vacuum filtration, compost (product: 100 percent nutrient-enriched composted sludge)
Alternative 14	Vacuum filtration, compost (product: 100 percent nutrient-enriched composted sludge)
Alternative 15	Anaerobic digestion, vacuum filtration, pipeline transport to solid waste recycling plant
Alternative 16	Vacuum filtration, pipeline transport to solid waste recycling plant

Reviewing the alternatives briefly, alternatives 1A and 1B are variations of the existing system of processing at the Central Plant, with truck-haul to Lowry Bombing Range for incorporation into the soil. Alternative 2 is the sytem recommended by CH2M HILL, slightly modified. As evaluated by CH2M-Hill, the final product of this system was a stored stockpile of air-dried sludge, the presumption being that users of the sludge would haul the product from the stockpile to the final reuse sites. As evaluated here, the truck-haul to the use site is included as part of the total system. Alternatives 3, 4, 5, 6 and 11 are options for processing prior to landfill. Alternatives 7, 8, 9, 13 and 14 are options for processing prior to composting and sale. Alternatives 10 and 12 are variations on Alternative 2, but with a different product mix.

Alternatives 15 and 16 are options for processing prior to transport to a regional solid waste processing plant. The feasibility of these alternatives is currently being studied by Ralph M. Parson, Inc. for the Denver Regional Council of Governments. The alternatives considered here are based on the assumption that the solid waste processing plant would be located 5 km [3 miles] distant from the District's plant and that digested sludge, at 25 percent solids content, would be accepted at the processing plant at no charge to the District (Reference 7).

COST OF ALTERNATIVE SYSTEMS

Economic evaluation of alternative sytems which incur future costs and accrue future benefits, always difficult, has become increasingly so in a time of severe price inflation and doubt concerning future resource costs and availability. In view of these difficulties, it is not surprising that differences of opinion exist in the engineering profession *vis-a-vis* the costs of certain processing and disposal activities.

The approach adopted in reevaluating the alternatives was to accept previous cost assumptions unless it appeared that an error of judgment had been made which might have a significant effect on the comparative costs of alternatives. After thorough review, the earlier assumptions were found to be generally acceptable, an exception being the omission of salvage values from the cost calculations. This omission has been rectified in order to conform with EPA cost-effectiveness guidelines. A more detailed discussion of cost assumptions is included elsewhere in this appendix.

The presentation of system costs is prefaced by a brief discussion of several factors that influence the economic evaluation.

Revenue

All systems considered that involve beneficial reuse have a potential for revenue generation. However, the market for sewage-sludge-derived products is somewhat uncertain; demand is low and competitive products are still relatively cheap and abundant. The potential revenues from beneficial reuse to be accrued in the Denver area have been estimated conservatively on the basis of experiences in other locations. Because of the doubts about the marketability of the products, the cost of each alternative assuming no revenue is presented in the cost tabulation together with a cost adjusted for revenue.

Inflation

Cost-effectiveness analysis guidelines published by the U.S. Environmental Protection Agency dictate that the effect of inflation should be neglected in cost comparisons of alternatives. The basis for this is the belief that, although future costs will escalate, the ability of the users to pay these costs will also escalate at the same rate. In addition, the discount rate used in the present-worth calculations is intended to take account of the declining value of money, the cost of borrowed funds and the opportunity cost of money. Because the alternative sludge management systems range from those with a high initial capital cost and low operating expenses to those with low initial capital costs and high operating expenses, the role of inflation in the cost comparison is crucial. For this reason, comparative costs are presented first without an inflationary factor and a second time with an inflationary factor of 8 percent.

Sunk Costs

A further difficulty was encountered in establishing a basis for equitably comparing the alternatives. Recently, the District began implementation of a plan to construct new anaerobic digestors. However, some of the alternatives being considered do not include anaerobic digestion as a necessary step in the total system. The question arises whether the cost of the digestors should be regarded as a sunk cost, to be ignored in the evaluation, or (since the funds are comitted and construction is about to begin) be included in all alternaives, irrespective of the need for this system component. Adopting either of these approaches penalizes alterantives that do not include anaerobic digestion. Because of this problem, the cost comparison was made in two ways: first, and most logically, the total costs of each system were compared, including a cost for digestion only where technically necessary; second, recognizing the realities of the situation, a comparison was made treating the digestion cost as a sunk cost.

Comparative Cost of Alternatives

Table 1 shows the present-worth cost of ten years of operation of each of the alternative systems. Similar information is presented in Table 2, but in this case the capital cost of the new anaerobic digestion system is treated as a sunk cost. A notable feature of the cost comparisons is the apparent economic attractiveness of alternatives 15 and 16, those that involve delivery of sludge to a regional solid waste processing facility. It should be remembered that at this stage these alternatives are poorly defined; the corresponding cost estimates are inevitably lacking in precision. Of course, the viability of these alternatives is predicated upon the existence of a facility of this type in the future. Because of the uncertainty, these alternatives are not strictly comparable with the other alternatives considered and are neglected in the following discussion. However, alternatives 15 and 16 are worthy of serious evaluation; further remarks on this subject are contained in the discussion that concludes this section.

A review of Table A-1 indicates that if inflation and revenue-generation potential are ignored then Alternative 2, the recommended plan, is one of a group of less costly alternatives, although by no means the least costly. If selection were to be based on this criterion alone, then Alternative 2 offers no notable economic advantages.

Considering the uninflated cost with revenue taken as a credit, Alternative 2 is again one of a group of less costly alternatives, but again not the cheapest. However, it should be noted that those alternatives that become significantly less expensive than Alternative 2 rely heavily upon revenue generated from sales; and, of course, doubts exist regarding the saleability of the product.

Turning to the cost comparison adjusted for an 8 percent inflation rate, the advantages offered by Alternative 2 become more apparent. Even if no revenue is accrued, Alternative 2 is the least expensive. If in fact sludge users collect dried sludge from the processing as assumed in the original evaluation, then the total cost of Alternative 2 will be reduced still further.

Table A-2 shows the cost of alternative systems treating the capital cost of anaerobic digestion as a sunk cost. As noted previously, this reduces the apparent cost of all alternatives that include anaerobic digestion. Thus the economic advantages of Alternative 2 are emphasized in the cost comparison.

ENVIRONMENTAL IMPACT OF ALTERNATIVE SYSTEMS

The environmental effects of the alternative systems fall into two general categories: the on-site effects--that is, the effects re-

Table A-1. COST OF ALTERNATIVE SYSTEMS

(million dollars)

Alternative	Present-worth cost of ten years of operation			
	Unadjusted		Adjusted for 8% inflation	
	without revenue	with revenue	without revenue	with revenue
1A	24.1	24.1	34.3	34.3
1B	24.7	24.7	30.1	30.1
2	24.0	19.3	17.7	10.8
3	24.2	24.2	26.8	26.8
4	22.5	22.5	25.9	25.9
5	33.3	33.3	30.2	30.2
6	23.6	23.7	23.6	23.6
7	30.3	19.6	35.1	19.3
8	34.0	17.0	45.1	20.1
9	33.8	25.9	40.1	28.5
10	28.8	20.5	24.4	12.3
11	26.4	26.4	30.8	30.8
12	28.9	20.7	24.5	12.4
13	28.4	20.5	33.8	22.2
14	27.0	14.5	36.4	18.0
15	16.8	16.8	17.8	17.8
16	10.1	10.1	13.3	13.3

Table A-2. COST OF ALTERNATIVE SYSTEMS TREATING THE CAPITAL COST OF ANAEROBIC DIGESTION AS A SUNK COST

(million dollars)

Alternative	Present-worth cost of ten years of operation			
	Unadjusted		Adjusted for 8% inflation	
	without revenue	with revenue	without revenue	with revenue
1A	24.1	24.1	34.3	34.3
1B	18.6	18.6	26.4	26.4
2	17.8	13.1	14.0	7.1
3	24.2	24.2	26.8	26.8
4	22.5	22.4	26.0	26.0
5	33.3	33.3	30.2	30.2
6	23.7	23.7	23.6	23.6
7	24.2	13.5	31.4	15.6
8	33.9	17.0	45.1	20.1
9	27.6	19.8	36.3	24.8
10	22.7	14.4	20.7	8.6
11	20.2	20.1	27.1	27.1
12	22.8	14.5	20.9	8.7
13	22.2	14.4	30.1	18.5
14	30.0	14.5	36.4	18.0
15	10.6	10.6	14.1	14.1
16	10.1	10.1	13.3	13.3

sulting directly from and at the site of the project components; and off-site effects. Off-site effects are the effects of the ultimate sludge disposal method used on the receiving environment.

Volume IV of the Sludge Management report to the District (Reference 8 in Section IV of the main text) is an environmental assessment of the alternative systems. The analysis emphasizes on-site impacts and concludes that Alternative 2 is the best option from an environmental standpoint. Off-site impacts are the subject of detailed analysis in subsequent sections of this report.

An independent review of the earlier assessment of on-site impacts led to general concurrence with the major conclusions presented. The more significant points emerging from the review are discussed below.

Process Options

Many of the alternatives are different only in that they employ different methods for stabilizing and dewatering sludge. The direct environmental implications of these different processing options are relatively insignificant when compared to the environmental consequences of different transportation and ultimate disposal methods. One exception to this is the relative resource economy of the processing options. All alternatives that include vacuum filters, filter presses, incinerators or heat treatment systems require chemicals and fuel for successful operation. Alternative 2, which employs anaerobic digestion, requires neither. In a time of doubt concerning future energy and materials costs and availability, the processing element of Alternative 2 offers a significant advantage.

Transportation

Alternatives 2, 10 and 12 involve pipeline transport of digested sludge to a remote location, while the remaining alternatives involve trucking of dewatered sludge or ash to an ultimate disposal site. Pipeline transport is superior because it consumes less energy, does not involve vehicular air-pollutant emissions and does not involve long-term impacts upon the community arising from traffic and noise.

PERFORMANCE OF ALTERNATIVE SYSTEMS

In this context, the performance of a sludge management system is used as an index of its effectiveness as a method of residual solids disposal. A number of elements contribute to system performance; they include process reliability, susceptibility to random physical and cultural disruption (due to earthquakes, labor disputes, etc.), susceptibility to resource shortages, and permanence.

Process Reliability

Some of the process components of the alternatives are inherently more reliable than others in making the required changes in sludge quality. Anaerobic digestion and air drying, the processes employed in Alternative 2, are well understood and widely applied. Properly designed and operated, they are proven to be reliable. Vacuum filtration (employed in alternatives 1A, 1B, 4, 6, 13 and 14) is probably the most reliable of the mechanical dewatering methods, followed by centrifugation (employed in alternatives 9 and 11) and filter presses (used in alternatives 3, 7 and 8). Incineration is a reliable process but is inherently more hazardous than are the mechanical processes. Heat treatment systems are not widely applied and have incurred some problems in continuous operation.

Susceptibility to Disruption

All alternatives involve processing activities at the main plant which would be disrupted during a labor dispute; the more complex processing options are more vulnerable, however, due to the need for continuous operation by skilled personnel. Pipeline transport would be less likely to be subject to disruption during a labor dispute than would trucking because it is not a labor-intensive operation. With respect to disruption of ultimate disposal operations, Alternative 2 would be less vulnerable than would other alternatives by virtue of its considerable storage capacity.

Alternatives involving pipeline transport are more vulnerable to disruption due to physical phenomena such as earthquakes and accidental damage during other, unrelated human activities. However, the Denver region is not particularly earthquake-prone, as discussed in the section on environmental setting.

Susceptibility to Resource Shortages

An alternative's susceptibility to resource shortages is directly related to its requirements for energy and chemicals. All alternatives that employ truck haul are relatively high energy consumers. All alternatives that involve mechanical dewatering are relatively high chemical consumers. By virtue of its processing method (anaerobic digestion), its transportation method (pipeline transport) and its use of free solar energy for dewatering, Alternative 2 emerges clearly as the best option with respect to this evaluation factor.

Permanence

Assuming that no unforeseen regulatory or physical constraints emerge, all alternatives considered can represent permanent solutions

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to the sewage sludge disposal problem. Permanent, in this context, means having a life in excess of 100 years.

THE APPARENT BEST ALTERNATIVE

An independent evaluation of the alternative sludge management systems led to a general concurrence with the results of the earlier evaluation, indicating that Alternative 2, anaerobic digestion, pipeline transport, air drying and beneficial reuse, is the apparent best alternative. This conclusion is drawn on the basis of the following:

1. It is economically attractive, particularly when inflation is taken into account.
2. Its economic appeal does not depend heavily upon revenue from sales that may not, in fact, occur.
3. It is flexible: the product mix can be adapted to the needs of the ultimate user; even under the worst circumstances, air-dried sludge in excess of need could be landfilled without seriously increasing costs.
4. It is conservative of energy and materials.
5. Its on-site environmental impacts are generally less serious than those resulting from the other alternatives.

Disadvantages of Alternative 2 are some doubt regarding long-term off-site effects (discussed in detail in a later section) and high initial cost. A cost-benefit analysis of Alternative 2 is included as Appendix G.

Because of the present funding arrangements for water pollution control facilities, projects with a high capital cost and low operating cost attract a larger proportion of Federal and State funds than do projects with low capital cost and high operating cost. Thus it is in the interest of local agencies responsible for sewerage service to select capital-intensive projects in order to maximize financing by outside agencies and minimize local user charges. On the other hand, it may be in the interest of the outside funding agencies to adopt an opposite approach in order to maximize the local share and distribute the available grant funds to a larger number of individual projects.

Basically, high initial capital cost can be regarded as a disadvantage only if its investment does not bring a return in terms of significantly reduced total costs. In the case of this project, and accepting that inflation should be accounted for in the cost calculations, it appears that the initial capital investment does in fact result in significantly reduced costs.

The cost estimates for alternatives 15 and 16 (processing and

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transport to a regional solid waste processing plant), admittedly somewhat lacking in precision at this stage, do indicate that economically these options and Alternative 2 are equally attractive. This is particularly true if sludge can be delivered to the plant undigested in order to retain a higher heat value. Although Alternative 2 is presently the apparent best alternative, it is recommended that a detailed environmental analysis of alternatives 15 and 16 be undertaken if there is a decision to implement a regional solid waste processing facility.

DETAILED DESCRIPTION OF ALTERNATIVES AND PROCESS FLOW DESIGNS

Alternative 1A

Alternative 1A will involve the continuation of existing modes of sewage sludge disposal. The Denver Northside Plant will, in 1985, deliver 20 metric tons [approximately 20 short tons] of dry sewage sludge to the Central Plant to be put into storage tanks. From the storage or holding facilities, sludge would be withdrawn and receive polymer conditioning, here estimated at 4 kg/metric ton [10 pounds per short ton] of sludge solids. The conditioned sludge would be dewatered on coil vacuum filters and trucked to the Lowry Bombing range, where smaller appropriate vehicles would apply the sludge to the land.

It is envisioned that the present vacuum filter capacity would need expansion to accommodate future flows, and chemical conditioning facilities would be added with the new coil vacuum filters. Expanded dewatered sludge hauling needs would necessitate the use of additional trucks. Existing coil filters would need repairs and renovation, as will the filtration building.

It is believed that the existing waste-activated sludge thickener can be used to thicken future design flows.

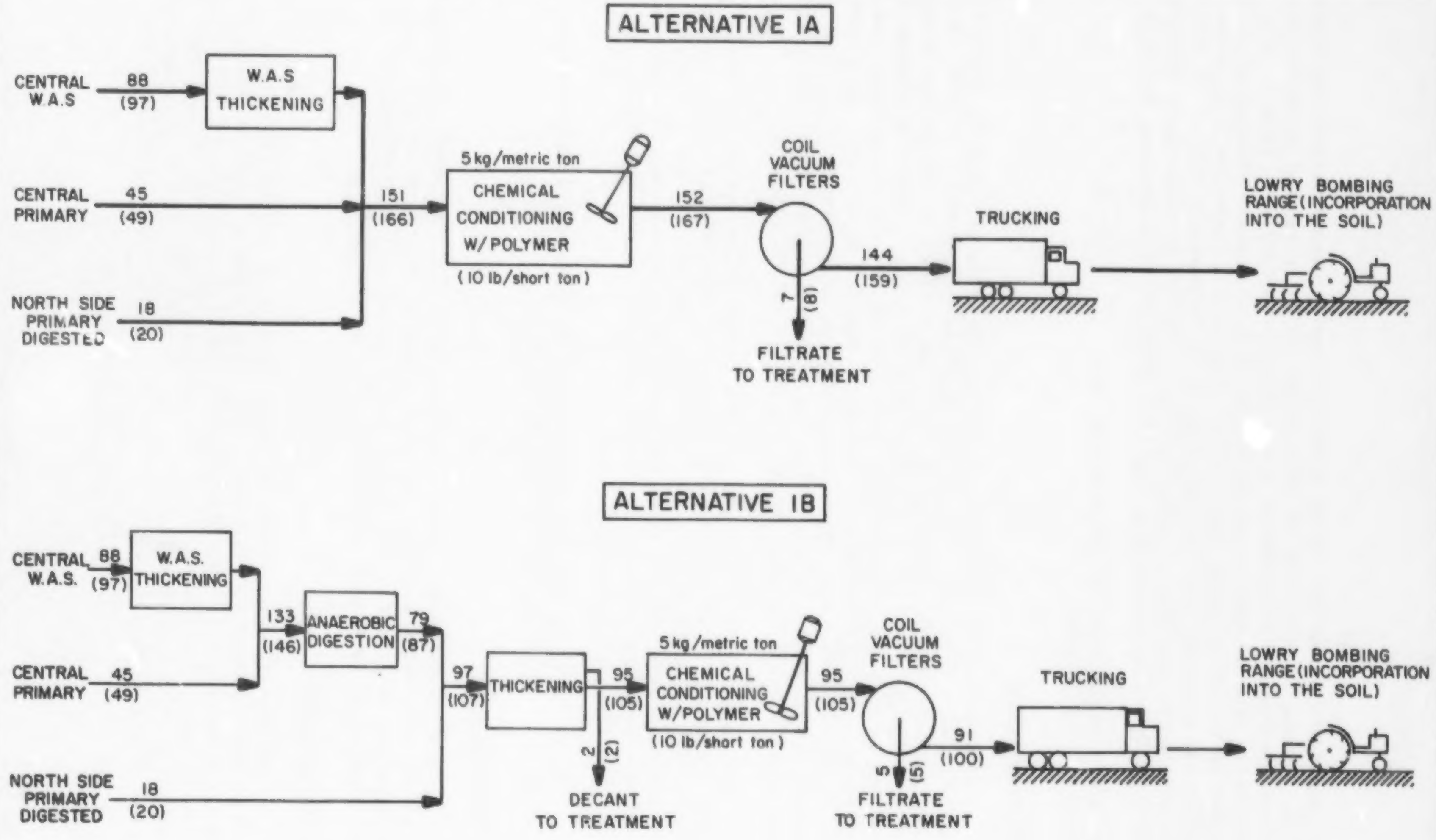
Alternative 1B

This alternative, similar to Alternative 1A, represents continuation of the existing system but with anaerobic digestion as an early processing step. This results in a marked reduction in dry solids to be handled in subsequent processing and disposal steps.

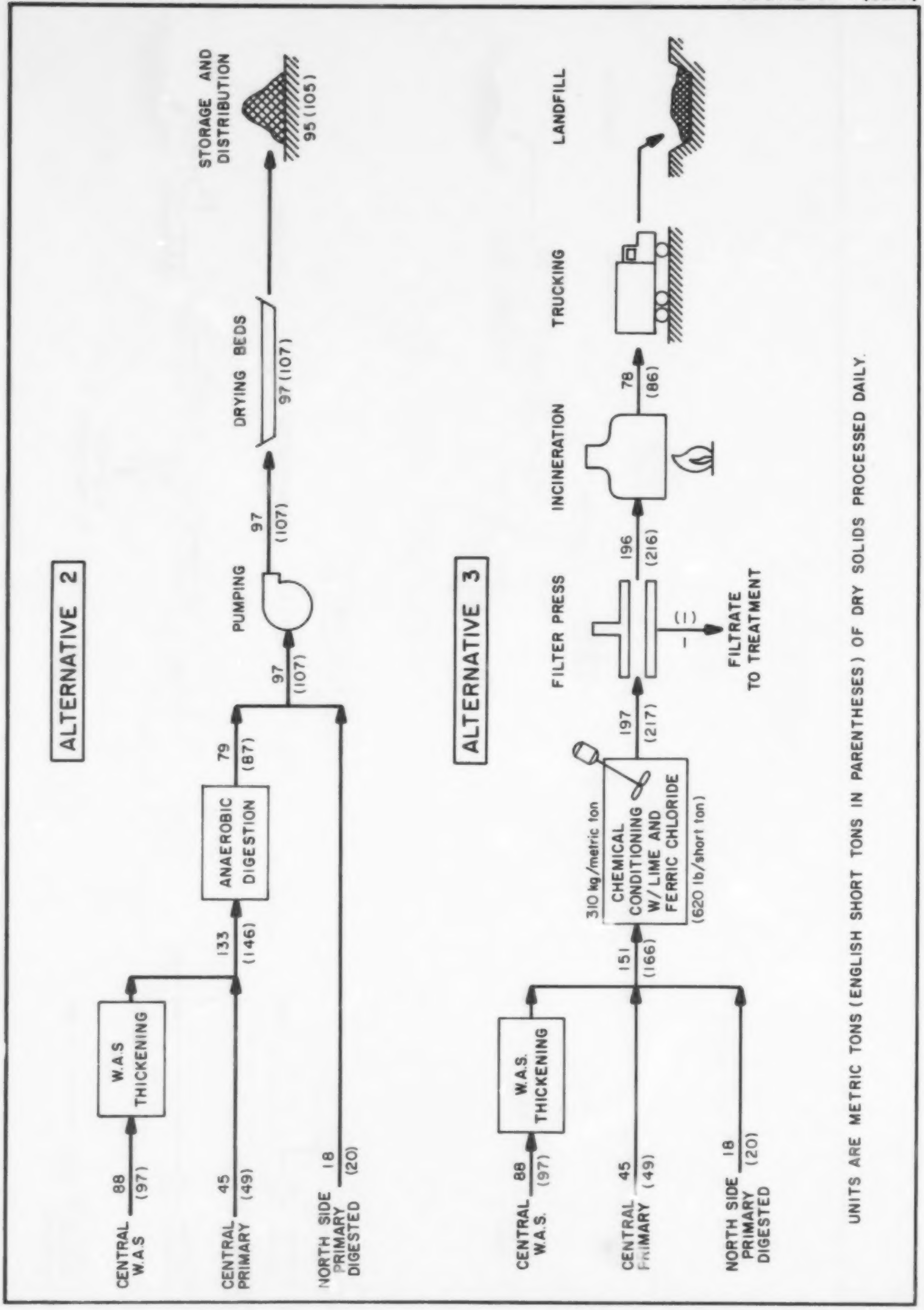
Alternative 2

Alternative 2 embodies the basic concept of beneficial sludge reuse through soil conditioning. All waste sludges would be anaerobically digested and then pumped, unthickened, to a drying and distribution center. The drying and distribution center, which is discussed in detail in *Metro Denver District Sludge Management, Volume III, Agricultural Reuse Predesign*, would air dry the sludge and stockpile it for

FIGURE A-1

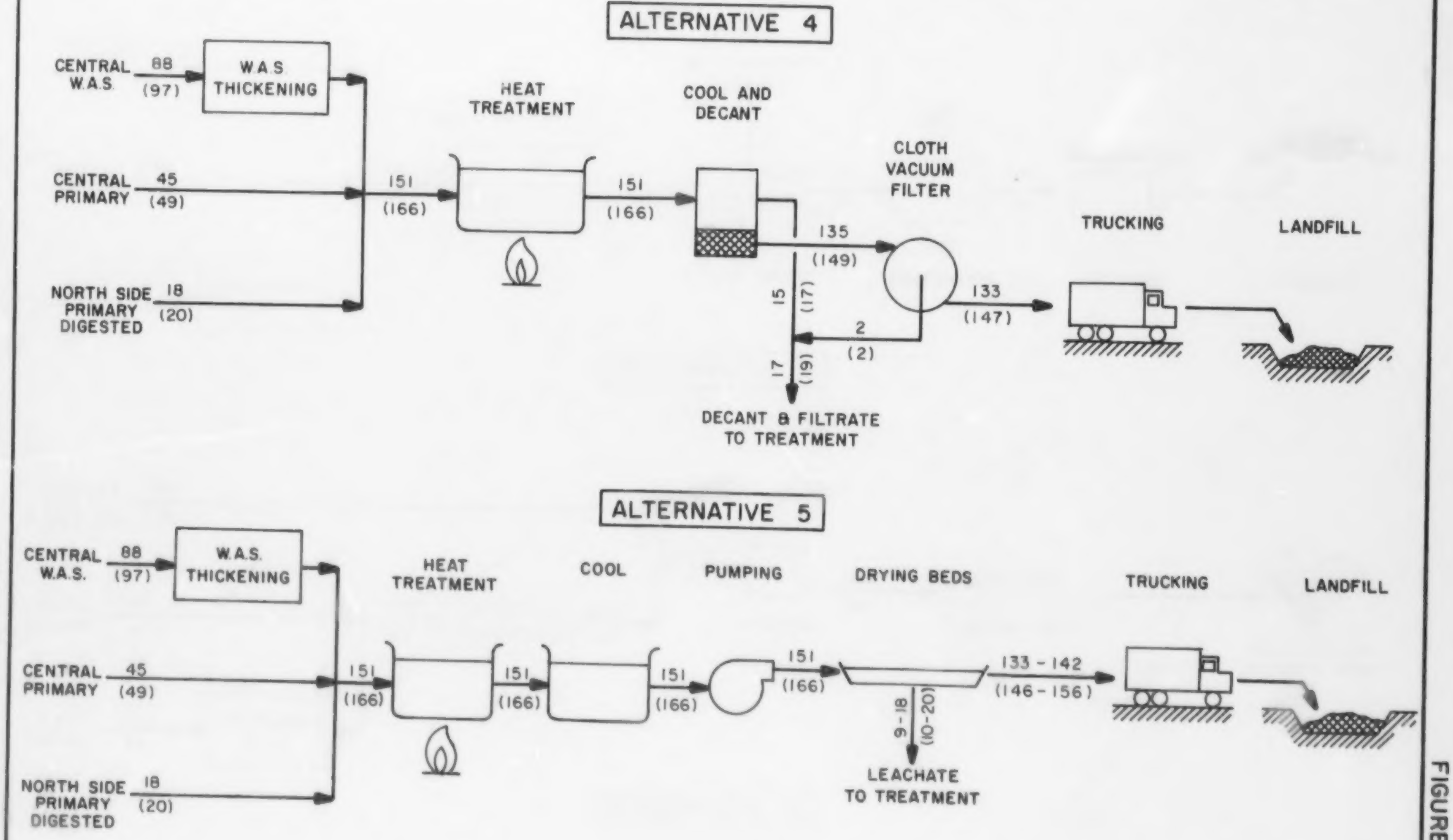

ALTERNATIVE IA
CENTRAL W.A.S
88
(97)
W.A.S THICKENING
CENTRAL PRIMARY
45
(49)
NORTH SIDE PRIMARY DIGESTED
18
(20)
151
(166)
5 kg/metric ton
CHEMICAL CONDITIONING W/POLYMER
(10 lb/short ton)
152
(167)
COIL VACUUM FILTERS
7
(8)
FILTRATE TO TREATMENT
144
(159)
TRUCKING
LOWRY BOMBING RANGE (INCORPORATION INTO THE SOIL)
ALTERNATIVE IB
CENTRAL W.A.S.
88
(97)
W.A.S. THICKENING
CENTRAL PRIMARY
45
(49)
133
(146)
ANAEROBIC DIGESTION
79
(87)
NORTH SIDE PRIMARY DIGESTED
18
(20)
97
(107)
THICKENING
2
(2)
DECANT TO TREATMENT
95
(105)
5 kg/metric ton
CHEMICAL CONDITIONING W/POLYMER
(10 lb/short ton)
95
(105)
COIL VACUUM FILTERS
5
(5)
FILTRATE TO TREATMENT
91
(100)
TRUCKING
LOWRY BOMBING RANGE (INCORPORATION INTO THE SOIL)

UNITS ARE METRIC TONS (ENGLISH SHORT TONS IN PARENTHESES) OF DRY SOLIDS PROCESSED DAILY.


ALTERNATIVE 2
CENTRAL W.A.S
88 (97)
W.A.S THICKENING
CENTRAL PRIMARY
45 (49)
133 (146)
ANAEROBIC DIGESTION
79 (87)
NORTH SIDE PRIMARY DIGESTED
18 (20)
97 (107)
PUMPING
97 (107)
DRYING BEDS
97 (107)
STORAGE AND DISTRIBUTION
95 (105)
ALTERNATIVE 3
CENTRAL W.A.S.
88 (97)
W.A.S. THICKENING
CENTRAL PRIMARY
45 (49)
NORTH SIDE PRIMARY DIGESTED
18 (20)
151 (166)
310 kg/metric ton
CHEMICAL CONDITIONING W/ LIME AND FERRIC CHLORIDE
(620 lb/short ton)
197 (217)
FILTER PRESS
1 (1)
FILTRATE TO TREATMENT
196 (216)
INCINERATION
78 (86)
TRUCKING
LANDFILL

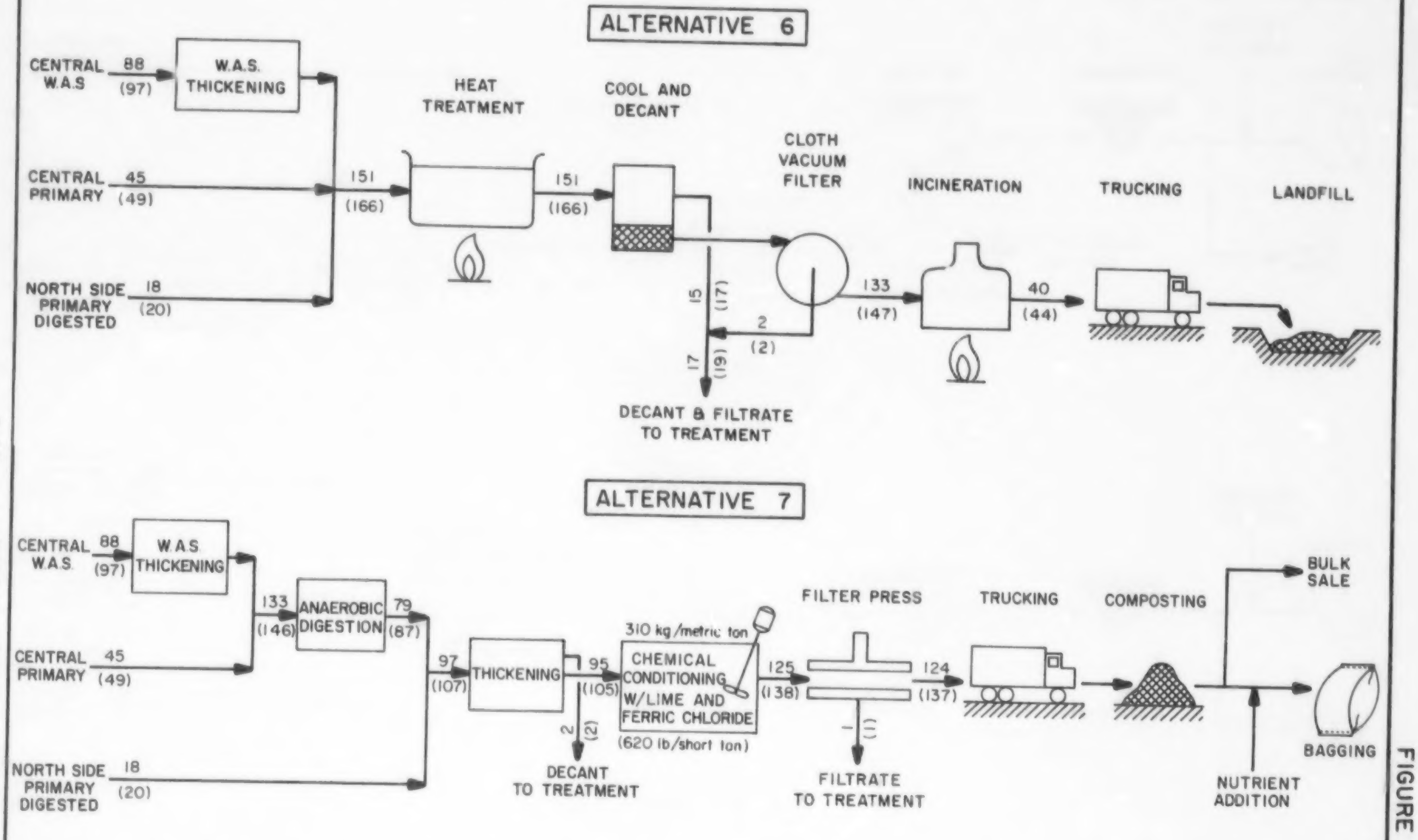
UNITS ARE METRIC TONS (ENGLISH SHORT TONS IN PARENTHESES) OF DRY SOLIDS PROCESSED DAILY.

FIGURE A-1 (cont.)


ALTERNATIVE 4
CENTRAL W.A.S.
88
(97)
W.A.S. THICKENING
CENTRAL PRIMARY
45
(49)
NORTH SIDE PRIMARY DIGESTED
18
(20)
151
(166)
HEAT TREATMENT
151
(166)
COOL AND DECANT
135
(149)
15
(17)
CLOTH VACUUM FILTER
2
(2)
17
(19)
DECANT & FILTRATE TO TREATMENT
133
(147)
TRUCKING
LANDFILL
ALTERNATIVE 5
CENTRAL W.A.S.
88
(97)
W.A.S. THICKENING
CENTRAL PRIMARY
45
(49)
NORTH SIDE PRIMARY DIGESTED
18
(20)
151
(166)
HEAT TREATMENT
151
(166)
COOL
151
(166)
PUMPING
151
(166)
DRYING BEDS
9-18
(10-20)
LEACHATE TO TREATMENT
133 - 142
(146 - 156)
TRUCKING
LANDFILL

UNITS ARE METRIC TONS (ENGLISH SHORT TONS IN PARENTHESES) OF DRY SOLIDS PROCESSED DAILY.

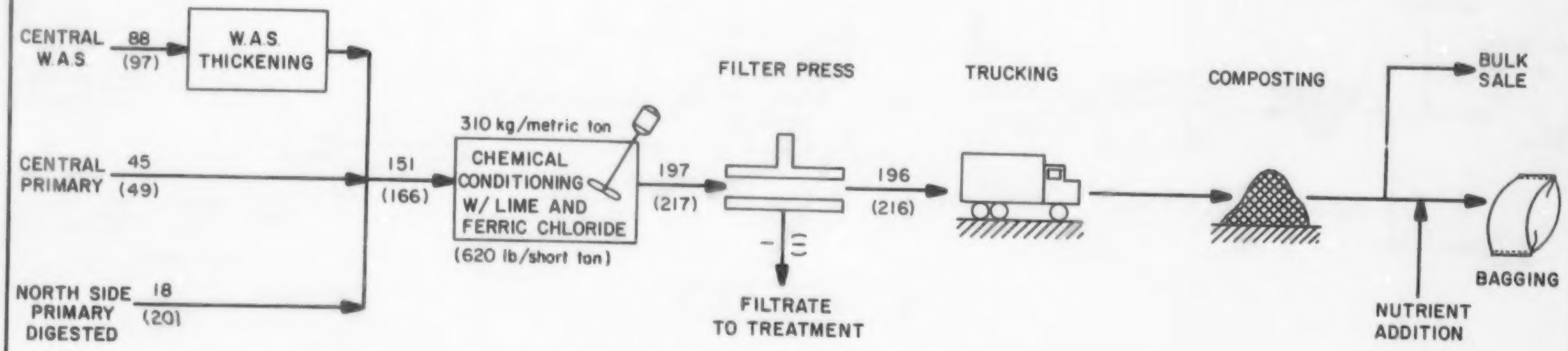
FIGURE A-1 (cont.)


ALTERNATIVE 6
CENTRAL W.A.S
88 (97)
W.A.S. THICKENING
CENTRAL PRIMARY
45 (49)
NORTH SIDE PRIMARY DIGESTED
18 (20)
151 (166)
HEAT TREATMENT
151 (166)
COOL AND DECANT
15 (17)
17 (19)
CLOTH VACUUM FILTER
2 (2)
DECANT & FILTRATE TO TREATMENT
133 (147)
INCINERATION
40 (44)
TRUCKING
LANDFILL
ALTERNATIVE 7
CENTRAL W.A.S.
88 (97)
W.A.S. THICKENING
CENTRAL PRIMARY
45 (49)
133 (146)
ANAEROBIC DIGESTION
79 (87)
NORTH SIDE PRIMARY DIGESTED
18 (20)
97 (107)
THICKENING
95 (105)
2 (2)
DECANT TO TREATMENT
310 kg/metric ton
CHEMICAL CONDITIONING W/LIME AND FERRIC CHLORIDE
(620 lb/short ton)
125 (138)
FILTER PRESS
1 (1)
FILTRATE TO TREATMENT
124 (137)
TRUCKING
COMPOSTING
BULK SALE
NUTRIENT ADDITION
BAGGING

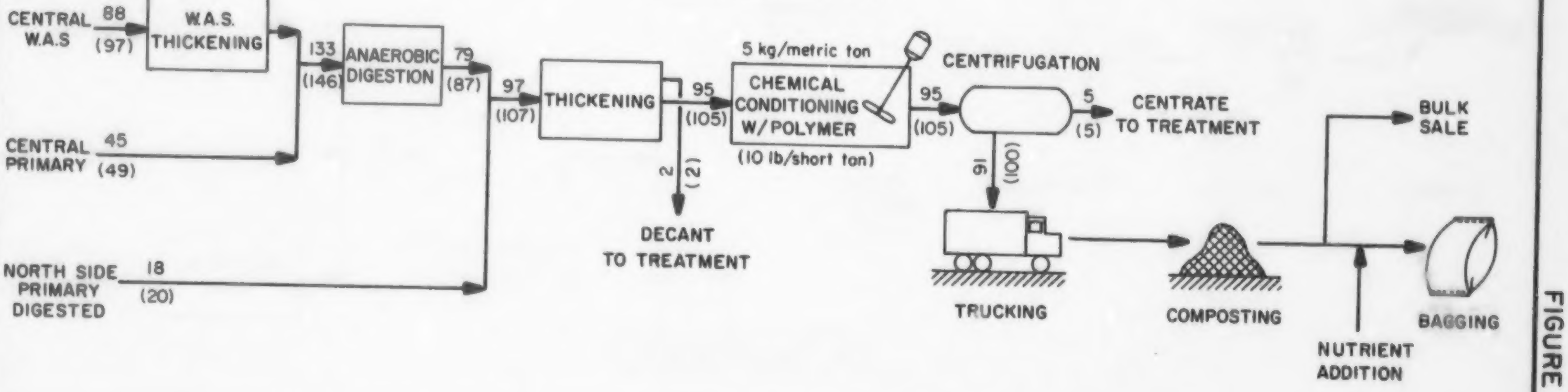
UNITS ARE METRIC TONS (ENGLISH SHORT TONS IN PARENTHESES) OF DRY SOLIDS PROCESSED DAILY.

FIGURE A-1 (cont.)

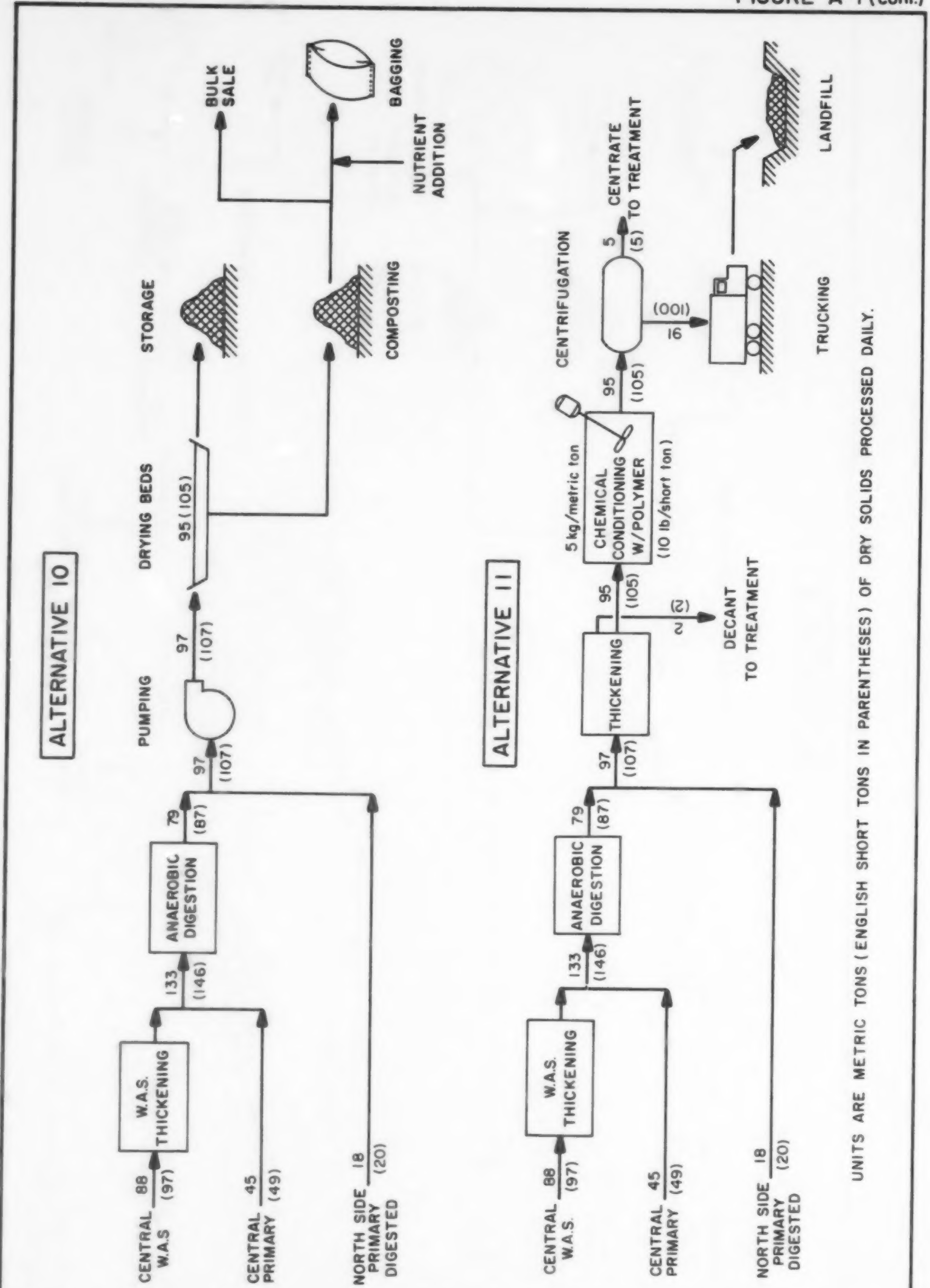
ALTERNATIVE 8


CENTRAL W.A.S
88 (97)
W.A.S. THICKENING
CENTRAL PRIMARY
45 (49)
NORTH SIDE PRIMARY DIGESTED
18 (20)
151 (166)
310 kg/metric ton
CHEMICAL CONDITIONING W/ LIME AND FERRIC CHLORIDE
(620 lb/short ton)
197 (217)
FILTER PRESS
1 (1)
FILTRATE TO TREATMENT
196 (216)
TRUCKING
COMPOSTING
BULK SALE
BAGGING
NUTRIENT ADDITION

ALTERNATIVE 9

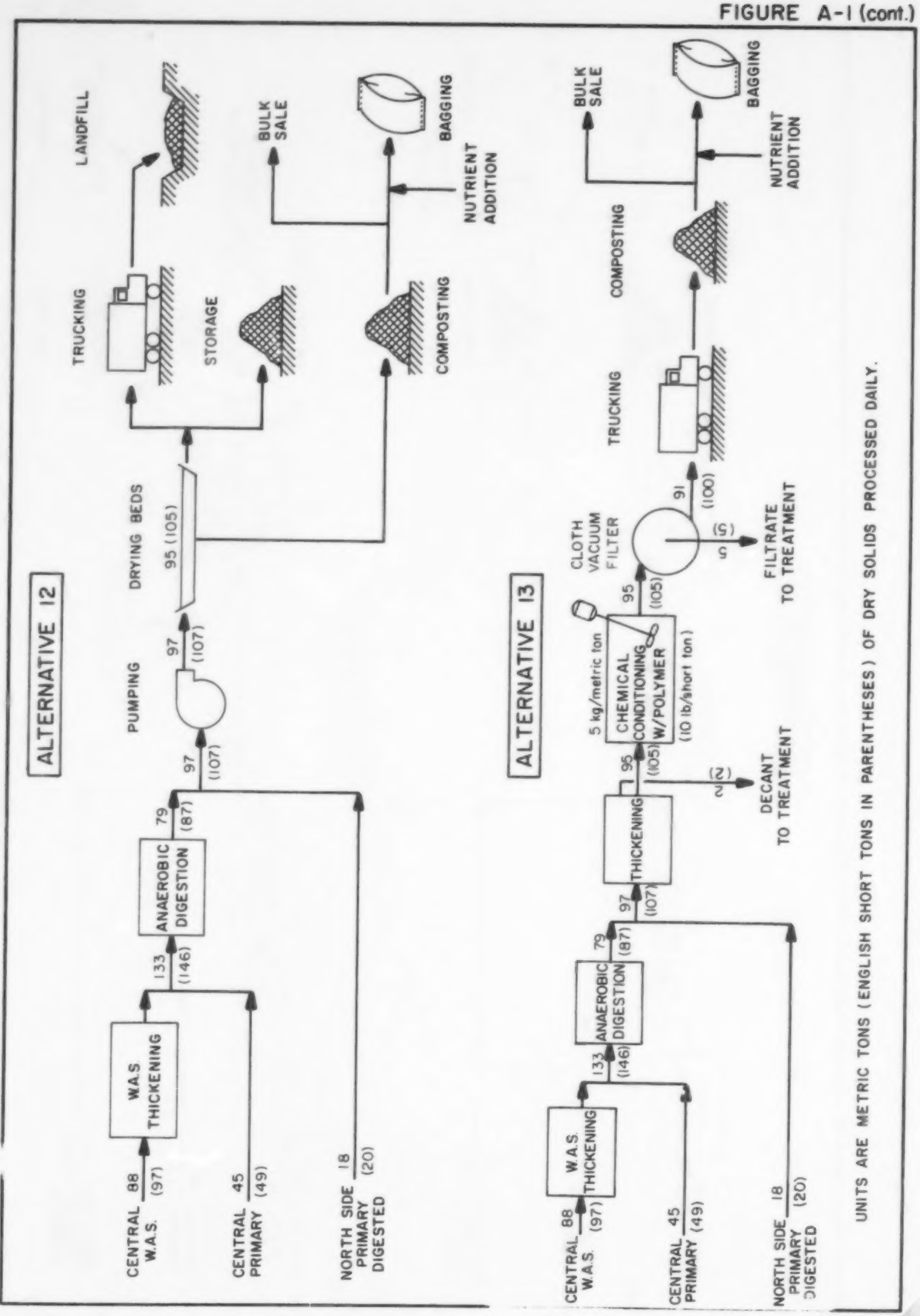

CENTRAL W.A.S
88 (97)
W.A.S. THICKENING
CENTRAL PRIMARY
45 (49)
133 (146)
ANAEROBIC DIGESTION
79 (87)
NORTH SIDE PRIMARY DIGESTED
18 (20)
97 (107)
THICKENING
2 (2)
DECANT TO TREATMENT
95 (105)
5 kg/metric ton
CHEMICAL CONDITIONING W/POLYMER
(10 lb/short ton)
95 (105)
CENTRIFUGATION
5 (5)
CENTRATE TO TREATMENT
91 (100)
TRUCKING
COMPOSTING
BULK SALE
BAGGING
NUTRIENT ADDITION

UNITS ARE METRIC TONS (ENGLISH SHORT TONS IN PARENTHESES) OF DRY SOLIDS PROCESSED DAILY.


ALTERNATIVE 10
CENTRAL W.A.S
88 (97)
W.A.S. THICKENING
CENTRAL PRIMARY
45 (49)
133 (146)
ANAEROBIC DIGESTION
79 (87)
NORTH SIDE PRIMARY DIGESTED
18 (20)
97 (107)
PUMPING
97 (107)
DRYING BEDS
95 (105)
STORAGE
COMPOSTING
BULK SALE
NUTRIENT ADDITION
BAGGING
ALTERNATIVE 11
CENTRAL W.A.S.
88 (97)
W.A.S. THICKENING
CENTRAL PRIMARY
45 (49)
133 (146)
ANAEROBIC DIGESTION
79 (87)
NORTH SIDE PRIMARY DIGESTED
18 (20)
97 (107)
THICKENING
2 (2)
DECANT TO TREATMENT
95 (105)
5 kg/metric ton
CHEMICAL CONDITIONING W/POLYMER
(10 lb/short ton)
95 (105)
CENTRIFUGATION
5 (5)
CENTRATE TO TREATMENT
16 (100)
TRUCKING
LANDFILL

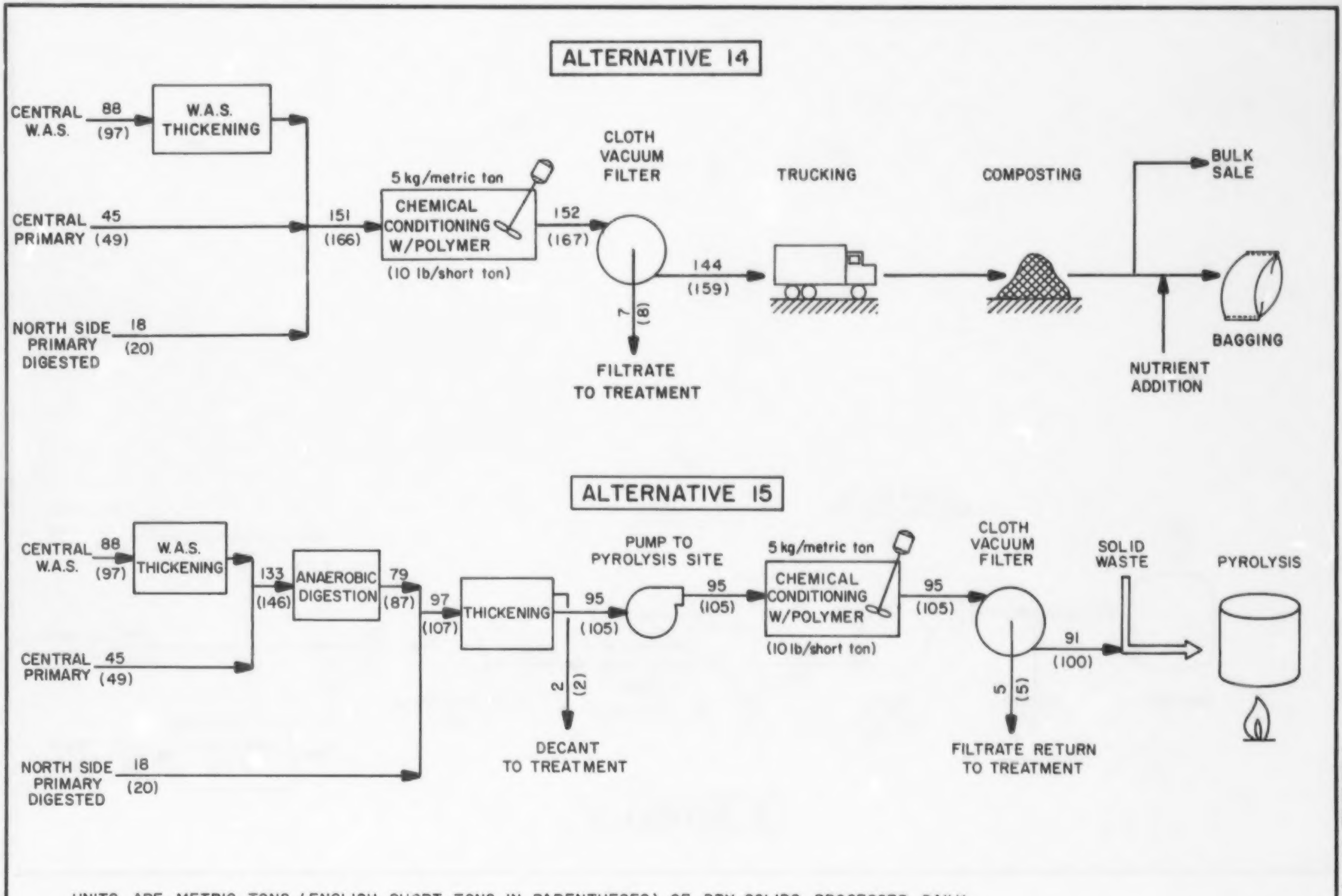
UNITS ARE METRIC TONS (ENGLISH SHORT TONS IN PARENTHESES) OF DRY SOLIDS PROCESSED DAILY.

FIGURE A-1 (cont.)

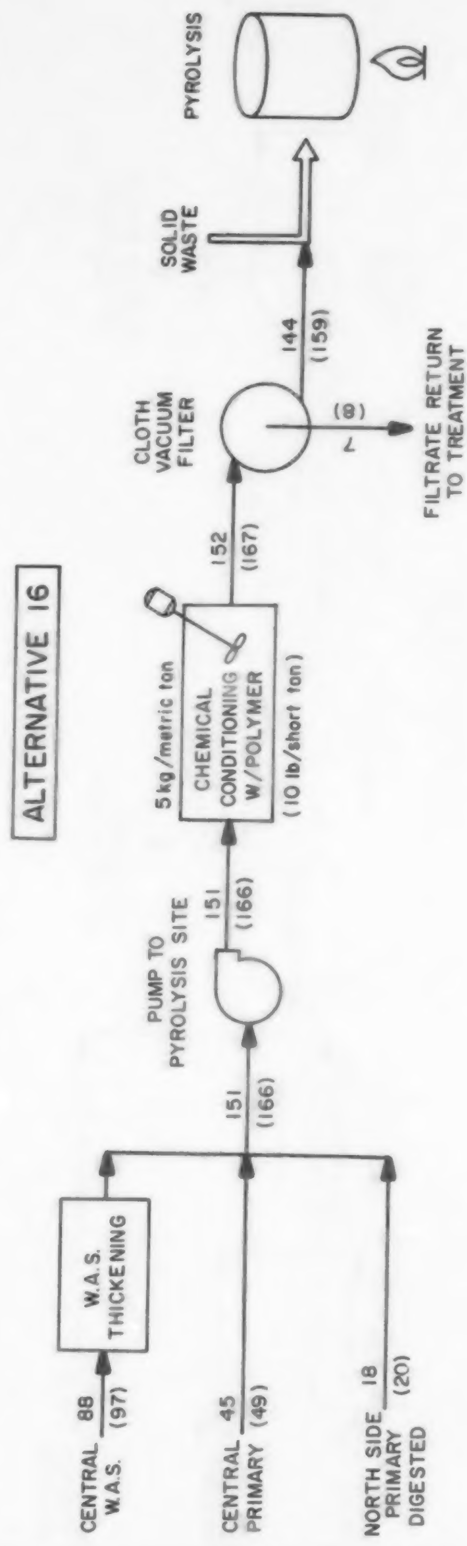

ALTERNATIVE 12
CENTRAL W.A.S.
88 (97)
CENTRAL PRIMARY
45 (49)
NORTH SIDE PRIMARY DIGESTED
18 (20)
W.A.S. THICKENING
133 (146)
ANAEROBIC DIGESTION
79 (87)
97 (107)
PUMPING
97 (107)
DRYING BEDS
95 (105)
TRUCKING
LANDFILL
STORAGE
COMPOSTING
BULK SALE
NUTRIENT ADDITION
BAGGING
ALTERNATIVE 13
CENTRAL W.A.S.
88 (97)
CENTRAL PRIMARY
45 (49)
NORTH SIDE PRIMARY DIGESTED
18 (20)
W.A.S. THICKENING
133 (146)
ANAEROBIC DIGESTION
79 (87)
97 (107)
THICKENING
2 (2)
DECANT TO TREATMENT
95 (105)
5 kg/metric ton
CHEMICAL CONDITIONING W/POLYMER
(10 lb/short ton)
95 (105)
CLOTH VACUUM FILTER
5 (5)
FILTRATE TO TREATMENT
91 (100)
TRUCKING
COMPOSTING
BULK SALE
NUTRIENT ADDITION
BAGGING

UNITS ARE METRIC TONS (ENGLISH SHORT TONS IN PARENTHESES) OF DRY SOLIDS PROCESSED DAILY.

FIGURE A-I (cont.)


ALTERNATIVE 14
CENTRAL W.A.S.
88 (97)
W.A.S. THICKENING
CENTRAL PRIMARY
45 (49)
NORTH SIDE PRIMARY DIGESTED
18 (20)
151 (166)
5 kg/metric ton
CHEMICAL CONDITIONING W/POLYMER
(10 lb/short ton)
152 (167)
CLOTH VACUUM FILTER
7 (8)
FILTRATE TO TREATMENT
144 (159)
TRUCKING
COMPOSTING
BULK SALE
NUTRIENT ADDITION
BAGGING
ALTERNATIVE 15
CENTRAL W.A.S.
88 (97)
W.A.S. THICKENING
CENTRAL PRIMARY
45 (49)
133 (146)
ANAEROBIC DIGESTION
79 (87)
NORTH SIDE PRIMARY DIGESTED
18 (20)
97 (107)
THICKENING
2 (2)
DECANT TO TREATMENT
95 (105)
PUMP TO PYROLYSIS SITE
95 (105)
5 kg/metric ton
CHEMICAL CONDITIONING W/POLYMER
(10 lb/short ton)
95 (105)
CLOTH VACUUM FILTER
5 (5)
FILTRATE RETURN TO TREATMENT
91 (100)
SOLID WASTE
PYROLYSIS

UNITS ARE METRIC TONS (ENGLISH SHORT TONS IN PARENTHESES) OF DRY SOLIDS PROCESSED DAILY.


ALTERNATIVE 16

CENTRAL W.A.S.
88
(97)
W.A.S. THICKENING
CENTRAL PRIMARY
45
(49)
NORTH SIDE PRIMARY DIGESTED
18
(20)
151
(166)
PUMP TO PYROLYSIS SITE
151
(166)
5 kg/metric ton
CHEMICAL CONDITIONING W/POLYMER
(10 lb/short ton)
152
(167)
CLOTH VACUUM FILTER
7
(8)
FILTRATE RETURN TO TREATMENT
144
(159)
SOLID WASTE
PYROLYSIS

UNITS ARE METRIC TONS (ENGLISH SHORT TONS IN PARENTHESES) OF DRY SOLIDS PROCESSED DAILY.

distribution. The center would include demonstration facilities showing the benefits of applying sludges to farmlands and would also have some subsurface disposal capacity to be used as an interim measure until a market for dried sludge develops. The subsurface storage would be accomplished by injecting liquid sludge several feet into the soil.

New anaerobic digesters, some of which are under construction, would be needed for the Central Plant sludge as would a new pumping and pipeline system. The drying and distribution center location, approximately 40 km [25 miles] east of Denver, has not been finalized and is one of three under consideration.

Alternative 3

In this alternative plan, raw sludge from the Central Plant and digested sludge from the Denver Northside Plant would be conditioned with lime and ferric chloride, estimated at 230 kg [500 pounds] of lime and 54 kg [120 pounds] of ferric chloride per ton of sludge solids. This conditioning would permit a filter press to dewater the sludge to 35 percent solids content. This level of dryness is desirable for the subsequent step of sludge incineration. It has been assumed that a multiple-hearth furnace would oxidize the sludge to carbon dioxide and water, leaving 35 percent of the original solids as ash. The ash would be trucked to a sanitary landfill or land application site within 40 km [25 miles] of Metropolitan Denver.

New chemical feed systems would be needed along with a completely new sludge filtration system. It has been assumed that all alternatives involving filtration would need an expansion of the present building and improvements to the ventilating systems. Trucking system improvements would include three new trucks for hauling incinerator ash to the disposal site. A multiple-hearth incinerator was chosen in preference to a fluidized-bed incinerator because we feel that the latter has lower reliability due to feed mechanism difficulties and to high corrosion and erosion from sludge and bed material, particularly upon the subsequent air pollution control equipment.

Alternative 4

Concern with the increasing costs of conditioning chemicals required prior to any sludge dewatering operation led to this alternative using heat treatment of sludge to break down the gel structure of the sludge particles and make them more amenable to settling and filtration. Raw Central and digested Northside sludges would be heated in a Zimpro Heat Treatment Unit and then cooled and decanted in a gravity separator. The thickened sludge, of approximately nine percent solids content, would be vacuum filtered through a cloth fabric on a belt or drum filter. The thickened sludge, of approximately 25 percent solids content, would be trucked to a sanitary landfill or a land disposal site.

The decant from the thickener would contain almost 10 percent of the original sludge solids and pollutants. This material would need treatment and represents a sizeable load upon any wastewater treatment facility. Published results of the Porteous heat treatment unit operation at Colorado Springs indicate that the decant liquor has contained 8,470 mg/l of COD and 3,800 mg/l of BOD.

New facilities needed for implementation of this alternative include a heat treatment unit, thickeners, expanded and renovated cloth filters and expanded trucking facilities. Additional treatment capacity may need to be added for the heat-treated decant liquor.

Alternative 5

Alternative 5 is similar to Alternative 4 in the treatment and disposal of sewage sludge except that the dewatering by vacuum filtration would be replaced by dewatering on drying basins with an underdrain return system. Since the drying beds would be removed from the Central Plant location and it would be difficult to pump sludges of 9 to 10 percent solids content, the heat-treated sludge would not be thickened, only cooled after dewatering. It is felt that pumping is to be preferred over the daily trucking of large quantities of thickened but watery sludge. It would be necessary to treat the leachate from the drying beds either at the Central Plant or at a new facility near the drying beds. Dewatered sludge would be trucked to a landfill or land disposal site.

New components needed for this alternative include a heat treatment unit, cooling tank, pumping and piping facilities, drying beds with under drains, leachate collection and treatment and a new trucking system.

Alternative 6

Alternative 6 is similar to alternative 4 in that raw Central Plant sludge and digested Denver Northside Plant sludge would be heat treated, cooled and decanted, and then filtered through a cloth, belt or drum, vacuum filter. However, instead of directly trucking the sludge to a landfill, in Alternative 6 an incinerator would be employed to reduce the sludge solids by 70 percent and the sludge water by 100 percent to lessen the trucking and land disposal costs.

The following new items of process equipment would be needed to implement this alternative: a heat-treatment unit, assumed to be manufactured by Zimpro; cooling and decant tanks, fabric media vacuum filters, along with conversion of existing coil filters to fabric filters; a multiple-hearth incinerator; and trucking facilities.

The decant and filtrate from heat-treated sludges contain substantial loads of pollutants that must be properly treated. This can require expansion of existing wastewater treatment units to accommodate the new load.

Alternative 7

Composting of sludge for beneficial reuse is the principal feature of Alternative 7. Central Plant sludges would be anaerobically digested, combined with Denver Northside Plant sludges and thickened in a gravity thickener. The thickened sludge, of approximately 5 to 7 percent solids, would be conditioned with lime and ferric chloride prior to dewatering in a filter press. Dewatered sludge would be trucked to a 200-hectare [500-acre] composting and storage area. Approximately 70 percent of the composted sludge would be sold in bulk, and 30 percent would receive nutrient enrichment to a fertilizer level of 6-6-6 and be bagged for urban sale.

New facilities necessary for implementation of this alternative include anaerobic digester, gravity thickeners, chemical conditioning systems, filter presses and trucking. A new composting facility would also be developed.

It is felt that the addition of lime to the sludge on the order of 25 percent by weight makes the sludge generally unacceptable as compost. For this reason Alternative 13 was developed to allow for a different conditioning system.

Alternative 8

Alternative 8 is very similar to Alternative 7 except that no digesters would be constructed at the Central Plant, and most of the sludges undergoing composting would be previously unstabilized. Again, the addition of lime to the sludge makes it a poor choice for general use as compost material, and Alternative 14 was developed to overcome this difficulty.

Alternative 9

Alternative 9 would also produce composted sludge as a final product with a variation in the sludge treatment system. Anaerobically digested sludges from both plants would be thickened and then chemically conditioned with polymers on the order of 4 kg [10 pounds] of polymer per ton of sludge solids. The conditioned sludges would be centrifuged to remove water and it is estimated that a sludge cake with 80 percent moisture could be achieved. The dewatered sludge would be trucked to a new 200-hectare [500-acre] composting and storage facility. From there, 70 percent of the composted sludge would be sold in bulk, and 30 percent would be nutrient enriched and sold as a bagged fertilizer.

New facilities required for this alternative include anaerobic digesters, gravity thickeners, chemical conditioning systems, centrifuges, trucking and composting. The use of polymers for sludge conditioning would make the sludge perfectly acceptable as compost.

Alternative 10

Alternative 10 is almost identical to Alternative 2 in that the sludge treatment processes and the final drying and distribution center would be the same. However, it is felt that the complete disposal system of distribution to farmers of bulk dried, stabilized sludge may not necessarily be sufficiently encompassing of beneficial uses. In particular, a substantial market need may exist for composted and enriched sludge for urban homeowners and landscapers. Alternative 10 adds to the process train of Alternative 2 the provision for composting, enriching and bagging a portion of the drying sludge. At this time it is difficult to specify the size of the market for composted and enriched sludge, and this disposal system could be reserved as a contingency measure for excess sludge disposal. An estimate of tonnage demand for costing purposes could be made after a market analysis for composted sludge. In the interim, the additional composting facilities are not reflected in any costs of alternatives.

Alternative 11

Alternative 11 is similar to Alternative 4 because it would provide a dewatered sludge for land disposal. Alternative 11 adds anaerobic digestion for Central Plant sludges in order to stabilize them and make them less noxious. The best treatment system, and attendant strong decant liquor, of Alternative 4 would be replaced by polymer treatment of the digested sludge, followed by centrifuge dewatering to produce a sludge cake containing 20 percent dry solids. This material would then be trucked to a sanitary landfill or other land disposal site.

New facilities needed for this alternative include anaerobic digesters, gravity thickeners, polymer feed systems, centrifuges and expanded trucking capability.

Alternative 12

Alternative 12 is basically identical to Alternatives 2 and 10 in producing anaerobically digested sludges for drying and distribution for beneficial reuse. This alternative includes a contingency plan to produce some composted and nutrient-enriched sludge for the urban market. Additionally, if due to unforeseen circumstances a market for dried or composted sludges is not adequately developed or is delayed in expansion, provisions would be made for trucking the dried sludges to a landfill site.

New components of Alternative 12 which would be in addition to those of Alternative 2 include composting pads, nutrient storage and addition facilities, a bagging machine and trucks for hauling sludge to a landfill. These additional facilities have not been included in the costs of Alternative 12 because the proportion of the sludge production duction likely to go to each disposal system has not been determined.

Alternative 13

Alternative 13 was developed to alleviate the concerns about lime content of composted sludge in Alternative 7. In Alternative 13, digested sludges would be thickened and treated with polymers. The conditioned sludge would be dewatered to approximately 25 to 30 percent dry solids content on a cloth vacuum drum or belt filter. Trucks would transport the dewatered sludges to a 200-hectare [500-acre] composting facility, from where it is estimated approximately 70 percent would be sold in bulk as compost. Approximately 30 percent of the compost would be enriched with nutrients to a 6-6-6 fertilizer level and sold to urban users. The fertilizer value of the compost could be adjusted to the specifications of large-quantity purchasers.

New facilities necessary for the implementation of this Alternative include anaerobic digesters, polymer mixing systems, trucking and a composting facility. It was calculated that the existing coil vacuum filters, if converted to fabric media with a loading rate of 17 kg/m^2/hour [3.5 $lb/(ft^2)(hr)$], could readily handle the expected load of digested sludge due to the solids reduction that occurs in an anaerobic digester.

Alternative 14

Alternative 14 is intended to provide a replacement for Alternative 8, which employs lime and ferric chloride conditioning of undigested sludges prior to dewatering in a filter press and composting. In Alternative 14, the sludges would be conditioned with a harmless and acceptable polymer and then dewatered on cloth vacuum filters. The use of filter presses can give drier sludge cakes, but with polymer conditioning could result in poor performance with rapid filter blending. The dewatered sludges would be trucked to a composting and distribution facility.

Alternative 15

Alternative 15 involves anaerobic digestion and thickening, followed by pipeline transport to a regional solid waste processing center assumed to be located 5 km [3 miles] from the District's Central Plant. At the processing center site, the sludge will be chemically conditioned and vacuum filtered to approximately 25 percent solids content. This product material will be accepted by the operators of the solid waste processing center at no charge.

Alternative 16

This alternative is similar to Alternative 15 except that anaerobic digestion is omitted in order to retain higher heat values in the final product material delivered to the solid waste processing center.

Assumptions Used in Costing Alternatives

1. Process cost curves and other costing assumptions used by CH2M-Hill were used in the cost analysis after review and verification. Changes in basic assumptions were made only where it was determined that the assumptions were clearly in error or were unacceptable for some other reason.

2. Sources for cost and performance data were as follows.

a. "Metro Denver District Sludge Management Report, Volume II," by CH2M-Hill, 1975, together with back-up calculations supplied by CH2M-Hill.

b. "An Analysis of the Sewage Sludge Disposal Problem in Southern California," by Engineering-Science, Inc. and J. B. Gilbert and Associates for EPA, 1974.

c. Composting cost and performance data were based upon estimates prepared by Dr. Gar Forsht of the Economic Research Service, USDA and supplied by CH2M-Hill.

d. Estimates of revenue from sale of composted sludge were based on information supplied by Mr. Kellogg of Kellogg Sales Company, Carson, California, the distributor of Los Angeles County's composted sludge.

e. Engineering-Science, Inc. in-house files on sludge processing performance and chemical dose rates.

3. All costs are related to an *Engineering News-Record* construction cost index of 2128, applicable to the Denver area in December 1974.

4. Alternative facilities are sized for 1985 sludge production projections.

5. Annual operation and maintenance costs derived for 1985 design flows were assumed to apply uniformly to the period 1975 through 1985.

6. Alternatives 1A and 1B involve continued use of existing coil filters and addition of new and similar filters to handle the increased quantities of sludge. Needed capacity of new filters (at a solids loading rate of 17 $kg/m^2/hr$ [3.5 $lb/ft^2/hr$]) was calculated on the basis of the demonstrated capacity of the old filters at 14.6 to 17 $kg/m^2/hr$ [3 to 3.5 $lb/ft^2/hr$]. The earlier estimates were in error on this point;

the existing filter capacity was calculated too low by a factor of five. Alternative 1B would result in substantially lower tonnage of sludge solids fed to the filters because of reductions in the digestion process and would need only a renovation of existing filters.

7. Vacuum filters were assumed to be belt or drum type. Performance and chemical dosage rates were assumed to be similar to those published by Los Angeles County Sanitation District.

8. Composting costs were recalculated on the basis of information contained in Dr. Gar Forsht's paper entitled "Estimated Processing Cost for Composting Sludge." The earlier estimates were in error in that a purchase of 400 hectares [1,000 acres] of land for composting was treated as an annual expenditure rather than a one-time-only initial cost.

9. It was assumed that for composting alternatives 30 percent of the sludge would be nutrient-enriched to a 6-6-6 fertilizer value.

Estimated Costs

Cost breakdowns for each alternative are shown in Tables A-3 and A-4. All costs are expressed in 1974 dollars. Salvage values were determined by straight-line depreciation on the basis of the estimated useful life of system components.

Table A-3. COST SUMMARIES USING 10 PERCENT DISCOUNT - NO INFLATION
(thousands of dollars)

Alternative	Σ capital	Σ salvage value (P.W.)	Difference	10 year O and M (P.W.)	Revenue	With digesters Sub-total w/o revenue	With digesters Total with revenue	Without digesters Sub-total w/o revenue	Without digesters Total with revenue[a]
1A	2,186	193	1,993	22,102	0	24,095	24,095	24,095	24,095
1B	9,893	2,390	7,503	17,229	0	24,732	24,732	18,568	18,568
2	25,759	7,913	17,846	6,157	4,710	24,003	19,292	17,839	13,129
3	14,236	3,045	11,191	13,014	0	24,205	24,205	24,205	24,205
4	12,636	1,664	10,972	11,484	0	22,456	22,456	22,456	22,456
5	29,060	7,437	21,623	11,693	0	33,316	33,316	33,316	33,316
6	20,636	3,720	16,916	7,484	0	23,680	23,680	23,680	23,680
7	15,503	3,309	12,194	18,175	10,748	30,369	19,621	24,205	13,457
8	8,538	1,249	7,289	26,655	16,947	33,944	16,997	33,944	16,997
9	15,675	3,358	12,317	21,481	7,846	33,798	25,952	27,634	19,788
10	26,616	7,913	18,703	10,108	8,238	28,811	20,573	22,692	14,409
11	19,911	9,780	10,131	16,228	0	26,359	26,359	20,195	20,195
12	26,746	7,913	18,833	10,108	8,238	28,941	20,703	22,822	14,539
13	12,705	2,893	9,812	18,557	7,846	28,369	20,523	22,205	14,359
14	5,830	846	4,984	21,979	12,474	26,963	14,489	26,963	14,489
15	10,813	2,714	8,099	8,744	0	16,843	16,843	10,679	10,679
16	2,763	485	2,278	7,841	0	10,119	10,119	10,119	10,119

[a] Over a ten-year period.

Table A-4. COST SUMMARIES USING 10 PERCENT DISCOUNT AND 8 PERCENT INFLATION
(thousands of dollars)

Alter-native	Σ capital	Σ salvage value (P.W.)	Differ-ence	10 year O and M (P.W.)	Revenue	With digesters		Without digesters	
						Sub-total w/o revenue	Total with revenue	Sub-total w/o revenue	Total with revenue[a]
1A	2,186	416	1,770	32,562	0	34,332	34,332	34,332	34,332
1B	9,893	5,160	4,733	25,383	0	30,116	30,116	26,424	26,424
2	25,759	17,084	8,675	9,071	6,939	17,746	10,807	14,054	7,115
3	14,236	6,573	7,663	19,173	0	26,836	26,836	26,836	26,836
4	12,636	3,592	9,044	16,919	0	25,963	25,963	25,963	25,963
5	29,060	16,054	13,006	17,227	0	30,233	30,233	30,233	30,233
6	20,636	8,031	12,605	11,026	0	23,631	23,631	23,631	23,631
7	15,503	7,144	8,359	26,777	15,835	35,136	19,301	31,444	15,609
8	8,538	2,696	5,842	39,270	24,967	45,112	20,145	45,112	20,145
9	15,675	7,248	8,427	31,647	11,559	40,074	28,515	36,382	24,823
10	26,616	17,084	9,532	14,891	12,137	24,423	12,286	20,731	8,594
11	12,913	6,005	6,908	23,908	0	30,816	30,816	27,124	27,124
12	26,746	17,084	9,662	14,891	12,137	24,553	12,416	20,861	8,724
13	12,705	6,245	6,460	27,339	11,559	33,799	22,240	30,107	18,548
14	5,830	1,826	4,004	32,381	18,377	36,385	18,008	36,385	18,008
15	10,813	5,859	4,954	12,881	0	17,835	17,835	14,143	14,143
16	2,763	1,046	1,717	11,551	0	13,268	13,268	13,268	13,268

[a] Over a ten-year period.

This Appendix contains descriptions of soils, by county, within areas which may receive sludge under the proposed recycling scheme.

APPENDIX B

SOILS

Table B-1. SOIL ASSOCIATIONS IN THE VICINITY OF DENVER

Soil association	Description	Map code*
ADAMS COUNTY		
Weld-Adena-Colby	Nearly level to steep, well-drained, loamy soils formed in wind-laid deposits; on uplands	27
Samsil-Shingle	Sloping to steep, excessively drained, clayey and loamy soils formed in materials from soft shale and sandstone; on uplands	72
Ascalon-Vona-Truckton	Nearly level to strongly sloping, well-drained and somewhat excessively drained, loamy and sandy soils formed in wind-laid deposits; on uplands	71
Nunn-Satanta	Nearly level, well-drained, loamy soils formed in alluvial materials that are underlain by gravel in some places; on terraces and fans	23
Alluvial land	Nearly level, poorly drained to well-drained, loamy and sandy soils formed in stream and river deposits; on flood plains	30
Terry-Renohill-Tassel	Gently sloping to steep, well-drained and somewhat excessively drained, loamy soils formed in materials from soft sandstone and shale; on uplands	6
Blakeland-Valent-Terry	Undulating to hilly, somewhat excessively drained, dominantly sandy soils; on uplands	5
Arvada-Heldt-Nunn	Nearly level, well-drained, loamy and clayey soils formed in alluvium; on terraces and fans	8
Platner-Ulm-Renohill	Nearly level to strongly sloping, well-drained, loamy soils formed in old alluvium on interbedded shale and sandstone; on uplands	73

Table B-1 (continued). SOIL ASSOCIATIONS IN THE VICINITY OF DENVER

Soil association	Description	Map code*
ARAPAHOE COUNTY		
Alluvial Land-Nunn	Deep, nearly level, mainly loamy and sandy soils; on flood plains and terraces	23
Weld-Adena-Colby	Deep, nearly level to sloping, loamy soils that have a clayey to loamy subsoil; formed in silty, wind-deposited material; on high-lying divides between creeks	3
Renohill-Buick-Litle	Sloping to steep, loamy soils that have a loamy to clayey subsoil; moderately deep and deep over shale or sandstone; on uplands	4
Nunn-Bresser-Ascalon	Deep, nearly level and undulating, loamy soils that have a clayey to loamy subsoil; developed in outwash; on uplands and terraces	42
Truckton-Bresser	Deep, rolling, loamy and sandy soils that have a loamy subsoil; on uplands	24
Stapleton-Bresser	Moderately steep soils that are loamy throughout; moderately deep and deep over arkosic sandstone; on foothills	43
Fondis-Weld	Deep, nearly level and gently sloping, loamy soils that have a clayey layer in the subsoil; formed mainly in silty, wind-deposited material; on foothills	27
OTHER AREAS		
Fluvaquents-Fluvents	Deep, somewhat poorly drained, nearly level, coarse-textured soils; on flood plains and low terraces; commonly flooded	18
Valent-Vona	Deep, excessively drained to well-drained gently sloping to moderately steep sandy soils; on uplands	148

Table B-1 (continued). SOIL ASSOCIATIONS IN THE VICINITY OF DENVER

Soil association	Description	Map code*
OTHER AREAS (continued)		
Ascalon-Olney-Vona	Deep, well-drained, nearly level loamy soils; on terraces with high water table	173
Nunn-Dacono-Altvan	Deep, well-drained, nearly level soils; on terraces and flood plains	174

*Map code numbers refer to Figure 7 in Section III

Source: Denver Region Water Quality Management Program

This Appendix contains tabular listings of plant species observed during the field reconnaissance phase of the EIS process, at the Lowry Bombing Range and at the sludge application portion of the Range. It also contains lists of common plants, birds and mammals in the Denver region.

APPENDIX C

BIOLOGY

Table C-1. LIST OF PLANT SPECIES OBSERVED DURING FIELD RECONNAISSANCE, AUGUST 7, 1975

Common name	Scientific name	Lowry Bombing Range[a]	Lowry sludge application area[b]
Tree			
Plains cottonwood	*Populus sargentii*	x	
Shrub			
Broom snakeweed	*Gutierrizia sarothrae*	x	
Rabbitbrush	*Chrysothamnus nauseosis*	x	
Willow	*Salix* sp.	x	
Herbs			
Alfalfa	*Medicago sativa*	x	x
Aster	*Aster* sp.	x	
Buffalobur	*Solanum rostratum*		x
Bull thistle	*Cirsium vulgare*	x	
Cocklebur	*Xanthium italicum*	x	
Common burdock	*Arctium minus*	x	
Common sunflower	*Helianthus annuus*	x	x
Coneflower	*Ratibida columnifera*	x	
Dandelion	*Taraxacum officinalis*	x	
Fanweed	*Thlaspi arvense*	x	
Fetid marigold	*Dyssodia papposa*	x	
Golden aster	*Chrysopsis* sp.	x	
Goosefoot	*Chenopodium leptophyllum*	x	x
Gumweed	*Grindelia squarrosa*	x	
Mikvetch	*Astragalus* sp.	x	
Narrow-leaved umbrella-wort	*Oxybaphus linearis*		x
Plantain	*Plantago spinulosa*	x	
Prickly lettuce	*Lactuca scariola*	x	
Prickly pear	*Opuntia polyacantha*	x	
Prickly poppy	*Argemone polyanthemos*	x	
Prostrate knotweed	*Polygonum aviculare*	x	
Prostrate pigweed	*Amaranthus graecizans*	x	
Redroot pigweed	*Amaranthus retroflexus*		x
Rocky Mountain beeplant	*Cleome serrulata*	x	
Russian thistle	*Salsola kali* var. *tenifolia*	x	x
Sand verbena	*Abronia fragrans*	x	
Scarlet falsemallow	*Sphaeralcea coccinea*	x	x
Sedge	*Carex* sp.	x	
Skeleton weed	*Lygodesmia juncea*		x

Table C-1 (continued). LIST OF SPECIES OBSERVED DURING FIELD RECONNAISSANCE, AUGUST 7, 1975

Common name	Scientific name	Lowry Bombing Range[a]	Lowry sludge application area[b]
Snow-on-the-mountain	*Euphorbia marginata*	x	
Stinging nettle	*Urtica dioica* ssp. *gracilis*	x	
Summer cypress	*Kochia scoparia*		x
Tansy mustard	*Descurainia pinnata*	x	
Tumble pigweed	*Amaranthus albus*		x
Umbrella plant	*Eriogonum effusum*	x	
Vervain	*Verbena bracteata*	x	
Yucca	*Yucca glauca*	x	
Grass			
Beardless wheatgrass	*Agropyron inerme*	x	
Blue grama	*Bouteloua gracilis*	x	
Buffalo grass	*Buchloe dactyloides*	x	
Cheat grass	*Bromus japonicus*	x	
Downy brome	*Bromus tectorum*	x	
Fescue	*Festuca* sp.	x	
Junegrass	*Koeleria gracilis*	x	
Little bluestem	*Andropogon scoparius*	x	
Milo	*Sorghum vulgare*		x[c]
Needle-and-thread	*Stipa comata*	x	
Oat	*Avena sativa*		x[c]
Red three-awn	*Aristida longiseta*	x	
Saltgrass	*Distichlis stricta*	x	
Sand dropseed	*Sporobolus cryptandrus*	x	
Sorghum sudangrass	*Sorghum bicolor X S. sudanense*		x[c]
Squirreltail	*Sitanion hystrix*	x	
Sudan	*Sorghum sudanense*		x[c]
Three-awn	*Aristida* sp.	x	
Western wheatgrass	*Agropyron smithii*	x	
Wheat	*Triticum sativa*	x	x[c]

[a] Portion of Site A not amended with sludge, shown in Figure 12.

[b] Sludge-amended portion of Site A, shown in Figure 12.

[c] Planted by Metro Denver Sewage Disposal District No. 1.

Table C-2. COMMONLY OCCURRING RANGE SPECIES IN THE DENVER AREA

Common name	Scientific name
Native, climax grass species	
Big bluestem	*Andropogon gerardi*
Blue grama	*Bouteloua gracilis*
Buffalograss	*Buchlöe dactyloides*
Indiangrass	*Sorghastrum nutans*
Junegrass	*Koeleria cristata*
Kentucky bluegrass	*Poa pratensis*
Little bluestem	*Andropogon scoparius*
Mountain muhly	*Muhlenbergia montana*
Needle-and-thread	*Stipa comata*
Needlegrass	*Stipa spartea*
Prairie dropseed	*Sporobolus heterolepis*
Red three-awn	*Aristida longiseta*
Sideoats grama	*Bouteloua curtipendula*
Sloughgrass	*Spartina pectinata*
Squirreltail	*Sitanion hystrix*
Switchgrass	*Panicum virgatum*
Western wheatgrass	*Agropyron smithii*
Associated woody plants, forbs and legumes - noxious weeds	
Canada thistle	*Cirsium arvense*
Field bindweed	*Convolvulus arvensis*
Halogeton	*Halogeton glomeratus*
Horsenettle, Caroline	*Solanum carolinense*
Horsenettle, white	*Solanum elaeagnifolium*
Povertyweed, silver-leaf	*Franseria discolor*
Povertyweed, woolly-leaf	*Franseria tomentosa*
Russian knapweed	*Centaurea repens*
Saint Johnswort	*Hypericum perforatum*
Sorghum almum	*Sorghum almum*
Sowthistle, perennial	*Sonchus arvensis*
Spurge, leafy	*Euphorbia esula*
Toadflax, Dalmation	*Linaria dalmatica*
Toadflax, yellow	*Linaria vulgaris*
Whitetop, common	*Cardaria draba*
Whitetop, hairy	*Cardaria pubescens*
Whitetop, tall	*Lepidium latifolium*
Associated woody plants, forbs and legumes - poisonous to livestock	
Arrowgrass	*Triglochin* spp.
Brake fern	*Pteridium aquilinum*
Chokecherry	*Prunus virginiana*

Table C-2 (continued). COMMONLY OCCURRING RANGE SPECIES IN THE DENVER AREA

Common name	Scientific name
Deathcamas	*Zygadenus* spp.
Larkspur	*Delphinium* spp.
Locoweed	*Oxytropis* spp.
Water hemlock	*Cicuta occidentalis*
Associated woody plants, forbs and legumes - others	
Black-eyed Susan	*Rudbeckia hirta*
Elderberry	*Sambucus racemosa*
Goldenrod, stiff	*Solidago altissima*
Horseweed	*Erigeron canadensis*
Prickly pear	*Opuntia rafinesquii*
Rose	*Rosa acicularis*
Russian thistle	*Salsola kali* var. *tenuifolia*
Sunflower	*Helianthus* spp.
Yucca	*Yucca glauca*

Source: Denver Regional Council of Governments Water Quality Management Plan.

Table C-3. NATIVE TREES AND ASSOCIATED SHRUBS IN THE DENVER AREA

Common name	Scientific name
Overstory and climax trees	
Alder	*Alnus tenuifolia*
American elm[a]	*Ulmus americana*
Box elder	*Acer negundo*
Douglas fir	*Pseudotsuga menziesii*
Hackberry	*Celtis occidentalis*
Narrow leaf cottonwood	*Populus angustifolia*
Pinyon pine	*Pinus edulis*
Plains cottonwood	*Populus sargentii*
Ponderosa pine	*Pinus ponderosa*
Rocky Mountain juniper	*Juniperus scopulorum*
Russian olive	*Elaegnus angustifolia*
Siberian elm[a]	*Ulmus pumila*
White fir	*Abies concolor*
Willow	*Salix* spp.
Associated shrubs	
American plum	*Prunus americana*
Bitterbrush	*Purshia tridentata*
Buffaloberry	*Shepherdia argentea*
Chokecherry	*Prunus virginiana*
Creeping mahonia	*Mahonia repens*
Gambel oak	*Quercus gambeli*
Hawthorn	*Crataegus* spp.
Indigobush	*Amorpha fruticosa*
Leadplant	*Amorpha canescens*
Mountain mahogany	*Cercocarpus montanus*
Ninebark	*Physocarpus monogynus*
Rabbitbrush	*Chrysothamnus* spp.
Redosier dogwood	*Cornus stolonifera*
Sagebrush	*Artemisia* spp.
Sandcherry	*Prunus besseyi*
Serviceberry	*Amelanchier* spp.
Skunkbrush	*Rhus trilobata*
Smooth sumac	*Rhus glabra*
Snowberry	*Symphoricarpos* spp.

[a] Species is not native but has volunteered from established plantings.

Source: Denver Regional Council of Governments Water Quality Management Plan.

Table C-4. COMMON BIRDS OF THE DENVER REGION

Common name	Scientific name
Aquatic birds	
Canada goose	*Branta canadensis*
Whistling swan	*Cygnus columbianus*
Lesser snow goose	*Chen hyperboea*
Mallard	*Anas platyrhynchos*
Gadwall	*Anas stepera*
American widgeon	*Marceca americana*
Pintail	*Anas acuta*
Green-winged teal	*Anas carolinensis*
Blue-winged teal	*Anas discors*
Cinnamon teal	*Anas cyanoptera*
Shoveler	*Spatula clypeata*
Redhead	*Aythya americana*
Canvasback	*Aytha valisineria*
Ring-necked duck	*Aytha collaris*
Lesser scaup	*Aytha affinis*
Common goldeneye	*Bucephala clangula*
Barrow's goldeneye	*Bucephala islandica*
Bufflehead	*Bucephala albeola*
Common merganser	*Mergus merganser*
Ruddy duck	*Oxyura jamaicensis*
Red-breasted merganser	*Mergus serrator*
Hooded merganser	*Lophodytes cucullatus*
Greater scaup	*Aytha marila*
Wood duck	*Aix sponsa*
Pied-billed grebe	*Podilymbus podiceps*
Eared grebe	*Podiceps caspicus*
Western grebe	*Aechmophorus occidentalis*
Hawks and falcons	
Turkey vulture	*Cathartes aura*
Sharp-shinned hawk	*Accipiter velox velox*
Marsh hawk	*Circus hudsonius*
Rough-legged hawk	*Buteo lagopus*
Ferruginous hawk	*Buteo regalis*
Red-tailed hawk	*Buteo borealis*
Swainson's hawk	*Buteo swainsoni*
Golden eagle	*Aquila chrysaëtos canadensis*
Bald eagle	*Haliaeetus leucocephalus*
Prairie falcon	*Falco mexicanus*
Sparrow hawk	*Falco sparverius*
Grouse, quail and pheasant	
Sharp-tailed grouse	*Pedioecetes phasianellus*
Bobwhite quail	*Colinus virgianus*
Ring-necked pheasant	*Phasianus colchicus*

Table C-4 (continued). COMMON BIRDS OF THE DENVER REGION

Common name	Scientific name
Shorebirds	
Great blue heron	*Ardea herodias*
Black-crowned night heron	*Nycticorax nycticorax*
American bittern	*Botaurus lentiginosus*
Sandhill cranes	*Grus canadensis tabida*
Virginia rail	*Rallus limicola limicola*
Sora rail	*Porzana carolina*
American coot	*Fulica americana americana*
American avocet	*Recurvirostra americana*
Killdeer	*Charadrius vociferus*
Spotted sandpiper	*Actitis macularia*
Willet	*Catoptrophorus semipalmatus*
Lesser yellowlegs	*Totanus flavipes*
Long-billed dowitcher	*Limnodromus griseus scolopaceus*
Wilson's phalarope	*Steganopus tricolor*
Common snipe	*Capella delicata*
Franklin's gull	*Larus pipixcan*
Black tern	*Chlidonias nigra surinamensis*
Pigeons and cuckoos	
Band-tailed pigeon	*Columba fasciata*
Rock dove	*Columba livia*
Yellow-billed cuckoo	*Coccyzus americanus*
Owls and goatsuckers	
Screech owl	*Otus asio*
Great-horned owl	*Bubo virginianus*
Short-eared owl	*Asio flammeus flammeus*
Barn owl	*Tyto alba pratincola*
Burrowing owl	*Spectyto cunicularia*
Poor-will	*Phalaenoptilus nuttalli*
Common nighthawk	*Chordeiles minor*
Terrestrial birds	
Ruby-throated hummingbird	*Archilochus coluoris*
Belted kingfisher	*Megaceryle alcyon*
Red-shafted flicker	*Colaptes cafer*
Common redpoll	*Acanthis linaria linaria*
Red-headed woodpecker	*Melanerpes erythrocephalus*
Hairy woodpecker	*Dryobates villosus*
Downy woodpecker	*Dryobates pubescens*
Eastern kingbird	*Tyrannus tyrannus*
Western kingbird	*Tyrannus verticalis*
Say's phoebe	*Sayornis saya*

Table C-4 (continued). COMMON BIRDS OF THE DENVER REGION

Common name	Scientific name
Traill's flycatcher	*Emphidonax traillii*
Horned lark	*Otocoris alpestris*
Barn swallow	*Hirundo erythrogaster*
Cliff swallow	*Petrochelidon albifrons*
Bank swallow	*Riparia riparia riparia*
Black-billed magpie	*Pica Pica hudsonia*
Common crow	*Corvus brachyrhynchos*
Black-capped chickadee	*Penthestes atricapillus*
Common bushtit	*Psaltriparus minimus*
Dipper	*Cinclus mexicanus unicolor*
Red-breasted nuthatch	*Sitta canadensis*
House wren	*Troglodytes aëdon*
Mockingbird	*Mimus polyglottos*
Catbird	*Dumetella carolinensis*
Brown thrasher	*Toxostoma rufum*
Robin	*Turdus migratorius*
Hermit thrush	*Hylocichla guttata*
Veery	*Hylocichla fuscencens fuscescens*
Golden-crowned kinglet	*Regulus satrapa*
Ruby-crowned kinglet	*Corthylio calendula*
Water pipit	*Anthus spinoletta*
Bohemian waxwing	*Bombycilla garrula pallidiceps*
Cedar waxwing	*Bombycilla cedrorum*
Loggerhead shrike	*Lanius ludovicianus*
Starling	*Sturnus vulgaris vulgaris*
Warbling vireo	*Vireo gilvus*
Orange-crowned warbler	*Vermivora celata celata*
Yellow warbler	*Dendroica petechia*
Ovenbird	*Seiurus aurocapillus*
Yellowthroat	*Geothlypis trichas*
Yellow-breasted chat	*Icteria virens*
American redstart	*Setophaga ruticilla*
House sparrow	*Passer domesticus domesticus*
Western meadowlark	*Sturnella neglecta*
Yellow-headed blackbird	*Xanthocephalus xanthocephalus*
Red-wing blackbird	*Agelaius phoeniceus*
Brewer's blackbird	*Euphagus cyanocephalus*
Common grackle	*Quiscaleus quiscula*
Brown-headed cowbird	*Molothrus ater*
Bullock's oriole	*Icterus bullocki*
Lazuli bunting	*Passerina amoena*
House finch	*Carpodacus mexicanus frontalis*
American goldfinch	*Spinus tristis*
Dickcissel	*Spiza americana*

Table C-4 (continued). COMMON BIRDS OF THE DENVER REGION

Common name	Scientific name
Rufous-sided towhee	*Pipilo erythrophthalmus*
Grasshopper sparrow	*Ammodramus savannarum australis*
Lark bunting	*Calamospiza melanocorys*
Vesper sparrow	*Pooecetes gramineus confinis*
Lark sparrow	*Chondestes grammacus strigatus*
Tree sparrow	*Spizella arborea ochracea*
Chipping sparrow	*Spizella passerina arizonae*
Field sparrow	*Spizella pusilla arenacea*
Lincoln's sparrow	*Melospiza lincolni lincolni*
Song sparrow	*Melospiza melodia*
McCown's longspur	*Rhynchophanes mccownii*
Chestnut-collared longspur	*Calcarius ornatus*
Townsend's solitaire	*Myadestes townsendi*

Table C-5. COMMON MAMMALS OF THE DENVER REGION

Common name	Scientific name
Big game	
Antelope	*Antilocapra americana*
Mule deer	*Odocoileus hemionus*
Small game	
Blacktail jackrabbit	*Lepus californicus*
Whitetail jackrabbit	*Lepus townsendi*
Fox squirrel	*Sciurus niger*
Desert cottontail	*Sylvilagus audubonii*
Eastern cottontail rabbit	*Sylvilagus floridanus*
Furbearers	
Coyote	*Canis latrans*
Opossum	*Didelphis marsupialis*
River Otter[a]	*Lutra canadensis*
Bobcat	*Lynx rufus*
Striped skunk	*Mephitis mephitis*
Shortail weasel	*Mustela erminea*
Longtail weasel	*Mustela frenata*
Black-footed ferret[a]	*Mustela nigripes*
Raccoon	*Procyon lotor*
Spotted skunk[a]	*Spilogale putorius*
Gray fox	*Urocyon cinereoargenteus*
Red fox	*Vulpes fulva*
Swift fox	*Vulpes velox*
Rodents, shrews, and bats	
Spotted ground squirrel	*Citellus spilosoma*
Thirteen-lined ground squirrel	*Citellus tridecemlineatus*
Whitetail prairie dog	*Cynomys gunnisoni*
Blacktail prairie dog	*Cynomys ludovicianus*
Ord kangaroo rat	*Dipodomys ordi*
Big brown bat	*Eptesicus fuscus*
Rodents	
Porcupine	*Erethizon dorsatum*
Least chipmunk	*Eutamias minimus*
Colorado chipmunk	*Eutamias quadrivittatus*
Plains pocket gopher	*Geomys bursarius*
Silver-haired bat	*Lasionycteris noctivagans*
Red bat	*Lasiurus borealis*
Hoary bat	*Lesiurus borealis*
Prairie vole	*Microtus ochrogaster*

Table C-5 (continued). COMMON MAMMALS OF THE DENVER REGION

Common name	Scientific name
Meadow vole	*Microtus pennsylvanicus*
California myotis bat	*Myotis californicus*
Long-eared myotis bat	*Myotis evotis*
Brown myotis bat	*Myotis lucifugus*
Small-footed myotis bat	*Myotis subulatus*
Fringed myotis bat	*Myotis thysanodes*
Long-legged myotis bat	*Myotis volans*
Eastern woodrat	*Neotoma floridana*
Northern grasshopper mouse	*Onychomys leucogaster*
Plains pocket mouse	*Perognathus flavescens*
Silky pocket mouse	*Perognathus flavus*
Hispid pocket mouse	*Perognathus hispidus*
Deer mouse	*Peromyscus maniculatus*
Western big-eared bat	*Plecotus townsendi*
Western harvest mouse	*Reithrodontomys megalotis*
Plains harvest mouse	*Reithrodontomys montanus*
Masked shrew	*Sorex cinereus*
Merriam shrew	*Sorex merriam*
Dusky shrew	*Sorex obscurus*
Mexican freetail bat	*Tadarida braziliensis*
Big freetail bat	*Tadarida molossa*
Northern pocket gopher	*Thomomys talpoides*
Meadow jumping mouse	*Zapus hudsonius*
Western jumping mouse	*Zapus princeps*

[a] Classed rare to near extinct due to constriction of habitat.

Source: Reference

Table C-6. COMMON AMPHIBIANS AND REPTILES OF THE DENVER REGION

Common name	Scientific name
Salamanders	
Barred tiger	*Ambystoma tigrinum mavortium*
Toads	
Great plains	*Bufo cognatus*
Woodhouse's	*Bufo woodhousei woodhousei*
Plains spadefoot	*Scaphiopus bombifrons*
Frogs	
Boreal chorous	*Pseudacris triseriata maculata*
Bull	*Rana catesbeiana*
Leopard	*Rana pipiens*
Turtles	
Snapping	*Chelydra serpentina*
Painted	*Chrysemys picta*
Yellow western box	*Terrapene ornata luteola*
Western spiny softshell	*Trionyx spiniferus hartwegi*
Lizards	
Lesser earless	*Holbrookia maculata*
Eastern short-horned	*Phrynosoma douglassi brevirostre*
Northern sagebrush	*Sceloporus graciosus graciosus*
Skinks	
Six-lined racerunner	*Cnemidophorus sexlineatus*
Snakes	
Eastern yellow-bellied racer	*Coluber constrictor flaviventris*
Prairie rattlesnake	*Crotalus viridis viridis*
Plains hognose	*Diadophis punctatus nasicus*
Central Plains milk	*Lampropeltis triangulum gentilis*
Smooth green	*Opheodrys vernalis*
Bullsnake	*Pituophis melanoleucus sayi*
Plains black-headed	*Tantilla nigriceps*
Wandering garter	*Thamnophis elegans vagrans*
Plains garter	*Thamnophis radix*
Red-sided garter	*Thamnophis sirtalis parietalis*

Source: Reference

Table C-7. COMMON FISHES IN STREAMS AND LAKES OF THE DENVER REGION

Common name	Scientific name
Brown trout	*Salmo trutta*
Carp	*Cyprinus carpio*
Tench	*Tinca tinca*
Creek chub	*Semotilus atromaculatus*
Fathead minnow	*Pimephales promelas*
Red shiner	*Notropis lutrensis*
Carp sucker	*Carpiodes carpio*
White sucker	*Catostomus commersonnii*
Channel catfish	*Ictalurus lacustris*
Black bullhead	*Ictalurus melaf*
Killifish	*Fundulas sp.*
White bass	*Lepibema chrysops*
Largemouth bass	*Micropterus salmoides*
Smallmouth bass	*Micropterus dolomieu*
White crappie	*Pomoxis annularis*
Black crappie	*Pomoxis nigromaculatis*
Green sunfish	*Lepomis cyanellus*
Blue gill	*Lepomis macrochirus*
Pumpkinseed	*Lepomis gibbosus*
Yellow perch	*Pesca flavescens*
Log perch	*Percina caprodes*
Darters	*Percidae* sp.

Source: Reference

This Appendix presents an overall discussion of the feasibility of applying municipal sludge to land, as evaluated by Engineering-Science, Inc.

APPENDIX D

SLUDGE APPLICATION TO LAND

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APPENDIX D

SLUDGE APPLICATION TO LAND

INTRODUCTION

The agricultural reuse of materials generated in the processing of municipal wastes is a contemporary issue that has as its philosophical base the belief that sewage wastes should be considered not as refuse but as useful resources. Past practices of sewage disposal have placed a burden on the environment in the form of air and water pollution and have essentially involved the elimination of a significant amount of nutrient resources from the ecosystems. Many communities in America are involved in programs of recycling municipal sludges and effluents on the land; many universities and public agencies are conducting long-term research projects on the effects of waste recycling on the environment. Preliminary results are appearing in increasing numbers in scientific and technical journals and other publications.

The intent of this appendix to the Metro Sludge EIS is to provide general information concerning the land application of sludge, with specific consideration to the chemical composition of Metro Denver sludge as it relates to agricultural reuse. Sources for more detailed or more situation specific information are given in the reference section.

The Metropolitan Denver Sewage Disposal District No. 1 proposes the transfer of anaerobically digested liquid sludge from the central plant to a drying and distribution site, where the sludge would be air dried and stockpiled for distribution for agricultural reuse purposes. The land application of sludge can be grouped into three general categories according to application rates; these are presented below and summarized in Table D-1.

> "The reuse of waste sludges for fertilization as shown in Table D-1 utilizes low loading rates (less than 45 tons per hectare per year [20 tons/acre/year]), depending on sludge characteristics, soil, and the crop grown. The objective is the maximization of crop production by full use of the nutrients present. Almost any soil suitable for high rate agricultural production is suitable for this type of operation. The key feature of this system is that a balance between the nutrients added and the nutrients removed with the crops should be maintained. Only the amount of organic material required to maximize crop production is applied.
>
> The 'high rate fertilizer' system uses higher loading rates (up to 170 metric tons per hectare per year [75 tons per acre per year]). The objective is to maximize the amount

Table D-1. THREE MAIN CATEGORIES FOR WASTE ORGANICS APPLICATION TO LAND

Method	Loading rates, metric tons/ha[a]		Objective	Suitable soils	Impact on quality	
	Annual	Maximum accumulation			Soil	Water
Fertilization	<2 to 45 depending on waste organics characteristic, soil and crop grown.	224 to 2240 to prevent excess accumulation of heavy metals or other pollutants in soil.	Maximize crop production by use of fertilizer to supply part or all of primary and/or micro nutrients.	Any soil which is suitable for high agricultural production.	Improves soil fertility and organics improve soil structure. No detrimental effects.	With a well managed system there would be no harmful effect on groundwater or surface water.
High rate fertilizer	<11 to >168	900 to 2240 to prevent toxic accumulations of pollutants in the soil.	Apply organics to cropped soil. Maintain crop while maximizing organics applications.	Generally fine textured soils with a high capacity to adsorb or precipitate large quantities of heavy metals or other pollutants.	May reduce soil usefulness for some crops or uses. Soil would probably be improved at lighter loadings. Accumulation of pollutants in soil must be monitored.	Possibly would result in excess nitrogen which could be leached to groundwater. Proper management of surface runoff would protect surface waters.
Disposal (landfill)	11 to several hundred	Several hundred to 2240 or more	To dispose of organics by incorporation in soil. A crop may or may not be grown between applications.	Generally fine textured soils with a high capacity to adsorb or precipitate large quantities of heavy metals or other pollutants.	Soil usefulness will likely be greatly reduced. Accumulation of pollutants in soil should be monitored.	Excess nitrogen could be leached to groundwater. Proper management would minimize potential for pollution from other materials.

[a] 1 metric ton/hectare = 0.446 English tons/acre

Source: Agricultural Reuse Program (Reference D-1).

> of sludge applied, with crop production secondary in importance. Solids suitable for this type of operation should be fine textured with a high capacity to absorb or precipitate large quantities of heavy metals. Eventually, continued unbalanced applications of waste organic materials may reduce the soil's usefulness to grow certain crops because of accumulations of heavy metals or salts. The application of the nitrogen contained in the waste organic materials would not be balanced by crop removal or natural denitrification, and accumulation of nitrogen in the soil would probably occur. Nitrogen compounds could eventually reach the ground water or surface system if proper precautions were not taken.
>
> The third general method of operation involves 'disposal' at very high loading rates (up to several hundred tons of waste sludge applied per hectare per year). The objective is to dispose of as much sludge as possible by incorporation into the soil with little or no emphasis on crop production. Fine textured soils will precipitate large quantities of heavy metals or other pollutants and are suitable for this type of operation. The end result of continued operation using the 'disposal' method is the potential impairment of the soil due to accumulation of salts, heavy metals, and nitrates in the soil. Leaching of nitrates, salts, and heavy metals from the soil into the ground water or carrying of these materials into the surface water regime is a potential hazard that must be considered in design." (Reference D-1)

The method characterized as "fertilization" is the one proposed by Metro Denver and is the one that will be focussed upon in this appendix as well as in the body of the environmental impact statement.

PLANT NUTRIENT REQUIREMENTS

Sixteen elements are known to be essential for plants to be able to complete their life cycle. Ten of these elements are required in relatively large amounts for plant growth. These macronutrients are: carbon, oxygen, hydrogen, nitrogen, phosphorus, potassium, sulfur, calcium, magnesium and iron. The remaining six micronutrients which are essential in trace amounts are: manganese, zinc, copper, boron, molybdenum and chlorine. Certain plants may not require one or more of the sixteen elements. Certain others require still other elements, or they must be able to substitute to a degree some elements for others. Some of the elements required by specific plants are sodium, selenium, cobalt and silicon. All of these nutrients with the exception of carbon are drawn by land plants mainly from the soil. Municipal sludge contains all of the essential plant nutrients in varying amounts.

SOILS AS SLUDGE ASSIMILATORS

Soil is primarily made up of mineral matter, organic matter, microorganisms, solutions and air. The assimilative potential of a soil depends upon its ability to filter, buffer, adsorb and absorb sludge constituents. Soils chemically and biologically transform sludge component and support plants which utilize the nutrients in them (Reference D-2).

Soil Suitability for Sludge Application

Physical properties that affect a soil's ability to assimilate sludge include: porosity, structure, texture (grain-size distribution) and mineralogy. Soil filterability is a property that determines how efficiently a soil can act as a physical filter of suspended particles and pathogenic organisms. Permeable soils of intermediate texture with enough colloidal content to trap particulates are generally the best filters. Soils that are least suitable for land application include those that are: 1) extremely fine-textures; 2) extremely coarse-textured, such as sands and gravels; 3) very shallow; 4) wet or undrained; 5) frozen; and 6) solonetz and others that are sodium saturated (Reference D-3).

Aspects of soil chemistry that are of importance to sludge assimilation include: 1) ion exchange capacity, 2) chemical alteration, and 3) soil pH and calcium reserve.

Ion exchange capacity refers to the total amount of cations and anions that are sorbable per unit of soil weight (expressed as milliequivalents per 100 grams of soil). Most soils have moderate to large cation-exchange capacities but only limited anion exchange capacities.

Allowable Sludge Application Rates

The cation exchange capacity is the sum of both the capacities of organic and inorganic soil components. The ability of a soil to retain heavy metals from sludge applications - and to keep them out of the ground and surface water and unavailable to plant tissues - is largely a function of its cation exchange capacity (Reference D-3). Equation D-1 shows the maximum permissible sludge loading rate as determined by the cation exchange capacity of a soil and the heavy metals content of the sludge, where CEC equals the cation exchange capacity of the unsludged soil in meq/100 g. and ppm equals mg/kg dry weight of sludge (Reference D-4). The constant-200 adjusts for the addition to the soil of some exchange capacity in the sludge (Reference D-5).

Total Sludge (dry wt. metric tons/hectare)=

$$\frac{73{,}000\ \ (\mathrm{CEC})}{\mathrm{ppm\ Zn} + 2(\mathrm{ppm\ Cu}) + 4(\mathrm{ppm\ Ni}) - 200} \qquad \text{(Equation D-1)}$$

This equation limits the heavy metal additions calculated as zinc equivalent to 10 percent of the cation exchange capacity. The zinc equivalent takes into account the greater plant toxicities of copper and nickel. This equation applies only to soil that can be adjusted and held at a pH of 6.5 or greater for a period of at least two years after sludge application (Reference D-10).

Chemical Reactions in Soil

The soil may chemically alter many of the materials which have been introduced into the profile through the addition of sludge. These alterations may lessen or increase the environmental impact of sludge application. For example, through the conversion of organic nitrogen to nitrate, a potential threat to groundwater quality and public health (Reference D-6) is introduced.

Soil pH and calcium reserve are very important properties that determine to what degree a soil can inhibit the solubility of heavy metals compounds. Contrasting properties of alkaline (calcareous) and acid soils are given below (Reference D-7):

Alkaline (Calcareous) Soils	Acid Soils
High in calcium	Low in calcium
High in pH and carbonate	Low in pH; no carbonate
Rich in nutrients	Poor in nutrients
Low solubility of heavy metal ions	High solubility of heavy metal ions
High activity of nitrogen fixing and nitrifying bacteria	Low activity of nitrogen fixing and nitrifying bacteria

Physical Effects of Sludge Addition to Soils

Sludge can act as a soil conditioner by the provision of those organic compounds that eventually become valuable humus in the soil. Sludge humus performs all the beneficial functions in the soil that any other kind of humus does: it holds large quantities of water, it improves soil structure and water absorption capacity (Reference D-8). It also improves root penetration and proliferation in the soil.

Sludge as a soil conditioner promotes desirable physical properties in soils such as friability (loose and crumbly rather than hard and cemented) and improved drainage (Reference D-9). Sludge residue decreases the bulk density of the soil (Reference D-10). In clay soil, sludge alleviates unfavorable characteristics by providing large pore spaces among soil aggregates. In sandy soil, it creates chemical reaction sites for nutrient exchanges, improves soil aggregation, and makes a good binder to hold the sand from blowing away (Reference D-11). It reduces the erodibility of all soils through enhancement of more resistant soil structure.

Adding sewage sludge initially increases the hydraulic conductivity of a soil, but the conductivity later decreases. Organic matter, through the activity of microorganisms, increases soil aggregation thereby increasing permeability. The subsequent decrease in hydraulic conductivity appears to be due to clogging of soil pores by microbial decomposition products.

Incorporation of sludge markedly influences the soil atmosphere. The low oxygen and high carbon dioxide contents initially result from high rates of liquid sludge application which can reduce root growth, nutrient uptake and plant growth. Other gas products of decomposition, such as methane and ethylene, can be detrimental to plants under high sludge application rates (Reference D-12). However, anaerobically digested air-dried sludge is stable enough so that decomposition reactions take place over a rather extended period of time and do not deplete soil oxygen (Reference D-32).

ENVIRONMENTAL CONSIDERATIONS AND CONSTRAINTS

The application of sewage sludge to the land can have effects on many functional components of the ecosystem. These effects, along with the major constraints to sludge application, are discussed in this section.

Surface Runoff

The area east of the Metropolitan Denver area is subject to heavy runoff during the spring thaw and during the summer when relatively short duration, high intensity thunderstorm activity occurs. Application of sludge during the spring and summer months could, if not handled correctly, contaminate surface runoff with elevated levels of nitrate, salts and suspended organic materials. Heavy metals contained in the organic materials are bound physically and chemically in the soil (when sludge is incorporated into the soil), and as long as the soil stays in place, little movement of heavy metals is expected. Special attention should be given to methods of containing surface runoff in order to prevent contamination of surrounding surface water supplies (Reference D-1).

Groundwater

If the application of sludge on irrigated farmlands is implemented by the private farms in the area, certain precautions concerning nitrogen loading must be observed so that a balance between the amount of nitrogen applied and the amount removed by the crops can be obtained. This should prevent excess nitrates from percolating into the groundwater table.

For dry land farm applications, the percolation problem is much less severe. Downward leaching of nitrates into the groundwater table would occur rather slowly, estimated by Pratt (Reference D-30) to average about 0.15 to 0.75 m/yr (0.5 to 2.5 ft/yr) through unsaturated strata in an area with characteristics similar to those of Adams County. The possibility of groundwater contamination from excess nitrates under excess sludge application regimes cannot be overemphasized.

Aesthetics

Land application of sludge can be managed so that no more of an aesthetic impact would result than with general agricultural field practices. Certain precautions can reduce any major aesthetic problems. Surface application of dry or liquid sludge should be followed shortly by incorporation into the soil either by discing or plowing. The time of the year when this is done should be controlled to prevent dust conditions from occurring. Farm practices in the Denver area are fairly well defined and a great deal of experience on the part of the farmers has been accumulated to prevent dust problems. Sludge should be applied only during the times of the year when proper dust prevention techniques can be observed (Reference D-1).

Odor

Since the Metro Denver sludge would be anaerobically stabilized, the odor potential would be quite low. The odor conditions are closely related to anaerobic bacterial action on volatile organic matter in both the liquid and solid portions of the sludge. Either a high degree of reduction of volatile matter, or chemical treatment to inhibit bacterial action, is necessary to prevent nuisance odors. The degree of volatile reduction achieved by anaerobic digestion is generally not less than 40 percent to achieve a stabilized sludge (Reference D-4).

The application of organic materials to the soil, followed by plowing in shortly thereafter, should be no more objectionable than the use of barnyard manure. With proper attention to application techniques, odors should not be detectable outside of the immediate vicinity of application. Those odors which are detectable when standing within the application area can best be characterized as faint tarry odors with a slight trace of ammonia. These odors will dissipate rapidly after application to the land.

Food Chain

The application of sludge to agricultural land on which crops entering the human food chain are grown is a matter of some concern, although there are no documented cases of disease resulting from the use of sludge. EPA guidelines require that the application of sludge to lands on which crops entering the human food chain will or may be grown must be examined closely in terms of hazards to human health and future land productivity. (Reference D-4)

The principle of food chain concentration (biological magnification) involves the accumulation and concentration of some substances as energy is passed in the form of food along the food chain. Thus, a substance which is contained in minute amounts in individual plants can become highly concentrated in certain organs in an animal which eats a large number of those plants.

Heavy Metals in Sludge--

Elements in sludge that are potential hazards to plants or higher species in the food chain are: boron, cadmium, cobalt, chromium copper, mercury, nickel, lead and zinc. The elements that are a significant potential hazard to the food chain through plant accumulation are cadmium, copper and zinc. Molybdenum has on rare occasions caused animal toxicities when they have pastured on soils naturally rich in this element. Sludge from Metro Denver District is not expected to contain toxic levels of molybdenum. Toxic metals added to soils are not a hazard to the food chain until they have entered an edible part of a plant, such as the leaf, grain, fruit, or edible root or tuber. Copper will cause severe plant injury before the content is high enough to be toxic to most animals. Cadmium and zinc, when added to the soil in sludge, can lead to increased food chain cadmium and zinc (Reference D-13).

Cadmium and Zinc--The Food and Drug Administration expects to specify the permissible level of cadmium in foods in the marketplace, possibly to be established at the current natural background levels (Reference D-13). Cadmium accumulates in the kidney and liver over many years. Kidney damage and hypertension have been related to increased cadmium levels in these organs. "Itai-Itai" disease was caused in Japan by increased dietary cadmium; cadmium suppressed calcium absorption and led to weak bones in older persons (Reference D-5).

The only apparent way proposed so far to ensure that the cadmium level in a food crop grown on a sludge-treated soil will not be a food-chain hazard, is to reduce the cadmium content of sludges to 0.5 percent of the zinc content, and as near as possible to 0.1 percent of the zinc content. In this way, zinc excess (at about 500 ppm Zn in leaves) would injure the crop before the zinc or cadmium content of the crop became a health hazard. Zinc appears to compete with cadmium at the sites of uptake and injury in animals, and the high zinc in crops grown on sludge-treated soil should serve to reduce cadmium uptake and accumulation. Grain, fruit, and edible roots have a lower zinc content than the leaves of the same plants. Cadmium is excluded even more strongly, so that the cadmium/zinc ratio of grain, fruit, and edible roots are one-half to one-tenth that of leaves. The choice of these types of crops in preference to leaf crops would minimize cadmium movement into the food chain. Further research is needed to determine what levels of cadmium and zinc are safe for the human food chain (Reference D-13).

Copper, Mercury and Lead--Copper, mercury, lead and some of the other elements in amounts normally found in sludges will not cause appreciable plant and food chain injury unless they are sorbed onto vegetative material by direct contamination and then ingested by animals in large amounts (Reference D-14).

Direct Ingestion of Sludge by Pasturing Domestic Animals--

Animals, notably cattle, are known to eat considerable quantities of soil as part of their daily diet. Sludge-applied soils, eaten by domestic animals, would short-circuit the capacity of the soil in screening contaminants from the food chain. Metro Denver District is now engaged in a research project aimed at determining accumulations of heavy metal elements in various tissues of animals fed controlled quantities of sludge.

Nitrogen

Nitrogen contained in digested sludge is the most immediate limiting factor to annual rates of application on a given tract of land. This is due to the fact that addition of excess nitrogen to the soil involves the risk of polluting the groundwater with nitrates. The threat of methemoglobinemia, caused by nitrates and nitrites in water supplies, are discussed under public health impacts. The processes which affect the form of nitrogen in soils (mineralization, nitrification, denitrification, immobilization, fixation, adsorption by cation exchange, volatilization, convection, dispersion, and plant uptake) may take place concurrently. The reates of these processes are determined largely by soil type and climate. The nitrogen content of the anaerobically digested liquid sludge at Metro Denver will consist of approximately 40 percent ammonia nitrogen and 60 percent organic nitrogen (Reference D-1). During drying, most of the ammonia and about half of the organic nitrogen are lost to volatilization.

Nitrogen is available to plants mainly as nitrates and ammonium. The ammonium form is rapidly converted by soil nitrifying bacteria to the nitrate form. Organic nitrogen is also mineralized to the nitrate form abailable to plants. Excess nitrates not taken up by plants can be leached into the groundwater reservoirs. Nitrogen is lost through denitrification and volatilization of ammonia and nitrogen gas to the atmosphere. Volatilization can account for at least a 25 percent loss of ammonia nitrogen, with this percentage increasing the longer the sludge is subject to air-drying. Approximately 30 percent of the remaining nitrogen in applied sludge becomes available for plant uptake in the first year, 15 percent in the second year, 10 percent in the third year and 5 percent in the fourth and succeeding years.

Nitrogen pollution problems can be controlled with correct management, which involves the formulation of a nitrogen balance for the sludge application program that prevents excessive nitrate leaching. The components of a nitrogen balance which must be known or estimated include:

1) Total nitrogen concentration of the applied sludge as percent of solids (N);
2) The amount of sludge applied in metric tons per hectare (R):
3) The amount of residual available nitrogen in the soil in metric tons per hectare (p);
4) The percent of nitrogen which is mineralized in a given year (c_2);
5) Nitrogen losses through denitrification and volatilization;
6) Potential annual uptake of nitrogen by each crop in Kg/ha/yr (U);
7) Proportion of the nitrogen in the crop removed from the land at harvest (c_1);
8) The amount of leaching to be allowed;
9) A timing pattern to retain the balance sufficiently close to an equilibrium.

The major elements of this balance are expressed in Equation D-2:

$$R = \frac{c_1 U}{1{,}000\ c_2 N} - p \qquad \text{(Equation D-2)}$$

The variable p is assumed to be zero for the first year, and for successive years is calculated according to the decay of residual available nitrogen (30 percent in the first year, etc.)

Nitrogen losses through denitrification and volatilization during air-drying should be estimated and subtracted from the total before N is computed. The amount of leaching allowed is determined by the initial groundwater quality, the size and rate of flow in the groundwater reservoir, and the size of the sludge application site. A certain amount of leaching is required in order to restrict the buildup of soluble salts in the soil root zone below tolerable limits. This leaching water will inevitably carry available nitrate forms to the groundwater. As a rule of thumb, sludge application rates should be such that no more than one half of the nitrogen in the applied sludge can be carried by the leaching fraction of irrigation water. Timing of sludge application depends on the site and the specific situation. It depends on 1) the rate of nitrification and, 2) assuming that nitrate ion movement occurs only with percolate movement, the moisture content properties of the soil, and 3) the amount of water added to the area. If sludge nitrogen is nitrified and moves below the root zone before it is absorbed by plants, it will percolate on to the groundwater. If leachate nitrate concentration is low during most of the year, high levels for a short period of time are more tolerable. Monitoring of the leachate must be included with the management program to compensate for unknown factors

(Reference D-15)

Heavy Metals

Heavy metals are found in digested sludge and usually occur in the soils as well. Toxic conditions are not caused merely by a high metal content in soil or sludge, but rather by the presence of heavy metals in soluble form. Heavy metals are adsorbed on the cation exchange sites of soil clays. Metals may also be precipitated, chelated, or complexed with organic matter in a form that is unavailable to plants (Reference D-16). The major heavy metals that are potentially hazardous to plants because of their amounts in sludge, availability in soils, and toxicities to plants or animals are zinc, copper, nickel and cadmium (Reference D-15). Successful treatment of sludge heavy metals by the soil occurs when they are adsorbed or otherwise held by the soil matrix so that they cannot be taken up by plants or leached into the groundwater.

The availability of heavy metals in sludge to crops is largely a function of soil pH and cation exchange capacity, phosphorus, calcium, organic matter, and crop variety, species, organ and age. The following summary presents methods of minimizing metal uptake by crops (Reference D-14):

Factors for Reducing Availability of Sludge Trace Elements and Their Uptake by Plants

Sludge:	Low concentration of trace elements
	Low Cd to Zn ratio
	High Phosphorus
	High organic matter
	High lime
Soil:	Neutral to high pH
	High cation exchange capacity
	High organic matter
	Calcareous soils
Crop:	Trace element tolerant variety and species
	Fruit and seeds compared with vegetative tissue
	Younger compared with older vegetative tissue

Plants vary greatly in tolerance to heavy metal toxicity and the relative tolerance of some plants is shown below (Reference D-14):

Relative Tolerance to Metal Toxicity

Very Sensitive:	Beet crops (chard, sugarbeet, redbeet), kale, mustard, turnip, tomato
Sensitive:	Beans, cabbage, collards, other vegetable crops
Moderately Tolerant:	Many farm crops, i.e., corn, small grains, soybeans
Tolerant:	Most grasses, i.e., fescue, lovegrass, Bermudagrass, perennial ryegrass
Very Tolerant:	Ecotypes of grasses

EPA guidelines for sludge application rates are based on the soil cation exchange capacity and the concentrations of zinc, copper and nickel, as shown above in Equation 1. The limits imposed by this equation are designed to keep down the level of heavy metals being absorbed by plants and to protect the fertility of agricultural lands (Reference D-4).

Pathogens

The control of pathogens is of importance because of possible direct exposure to sludge in the handling and application steps and in the food chain. Although anaerobic digestion reduces the pathogen content of sludge, a significant number of pathogens may survive the process (Reference D-2). There is no documented evidence of disease caused by the use of digested sludge on agricultural land, yet some pathogenic organisms have been reported to survive in soils for long periods of time.

Four major groups of pathogenic organisms that are found in municipal wastewater are: 1) *Salmonella, Shigella* and *Mycobacterium* bacteria; 2) the protozoa, *Entamoeba hystolytica* and *Naegleria*; 3) Helminth parasites, *Ascaris, Ancyclostoma, Necator, Taenia,* and *Tricahuris;* and 4) viruses. Of the 150 viruses isolated from sewage, only two, the causative agents for poliomyelitis and infectious hepatitis, have been found to be epidemiologically significant (Reference D-15). The survival and movement of viruses through the soil is the subject of much research (Reference D-16). Fecal and total coliform bacteria, although not pathogenic, are used for pathogen determinations because of their large numbers and the ease of measurement as an indication of the presence of other enteric bacteria and pathogens (Reference D-15).

Additional pathogen reduction beyond that attained by stabilization can be achieved by the following methods:

1) Pasteurization for 30 minutes at 70°C (158°F);
2) High pH treatment, typically with lime, at a pH greater than 12 for 3 hours;
3) Long-term storage of liquid digested sludge for 60 days at 20°C (68°F) or 120 days at 4°C (40°F);
4) Complete composting at temperatures above 55°C (131°F) for at least 30 days;
5) Use of chlorine or other chemicals to stabilize and disinfect sludge (Reference D-4, D-2).

Current research shows preliminary promise in the use of high energy electrons for disinfection of sludge passing in a thin stream in a specifically adapted process (Reference D-31).

The viability of pathogens is extremely variable and may be from a few hours to several months. Among the factors influencing the survival of pathogens in the soil and on vegetation are:

1) Type of organism;
2) Temperature - lower temperature increases viability;
3) Moisture - longevity is greater in moist soils than in dry soils;
4) Type of soil - neutral, high moisture holding soils favor survival; and
5) Organic matter - the type and amount of organic matter present may serve as a food or energy source to sustain the microorganisms (Reference D-2).

The potential for groundwater contamination by pathogens is dependent on the ability of pathogens to survive and move through the soil system. Fine clay solids are more effective than sandy soils for the removal of pathogens. A soil system is generally efficient in removing pathogens unless rapid movement of sludge (or later, irrigation water) occurs through large cracks in the soil profile. Generally, surface water contamination constitutes a greater hazard through surface erosion or surface water runoff during periods of snowmelt or thunderstorm precipitation (Reference D-2).

EPA guidelines state that sludge-treated land should not be used for human food crops to be eaten raw until three years after sludge application. Sludge applied to crops which are cooked or processed be before consumption, to pastures, or to crops used for forage, should test negative for pathogens by normally applied analytical procedures. EPA suggests the use of *Salmonella* and *Ascaris* as pathogens of choice for a monitoring program (Reference D-4).

Salts

The soluble ions calcium, magnesium, sodium, potassium, chlorine and carbonate are the principle inorganic ions added to soil in sludge and mineralized from sludge organic materials in large concentrations. These highly soluble salts are involved in exchange reactions in the soil and, depending upon the composition of the adsorbed phase, will be temporarily retained and slowed in their passage through the soil. In the Denver area, normally there is sufficient excess irrigation or rain water available to flush these ions through the soil and into the groundwater table. In arid and semi-arid parts of the country, water is relatively expensive and thus scantily used, and rainfall is infrequent, resulting in an accumulation of salts in the upper soil layers. This accumulation can, in time, prove deleterious to crops. Frequently, in the case of high sodium concentrations, soil permeability is drastically decreased before sodium directly affects plant growth. This occurs with too high a percentage of sodium ions on the exchange sites when sodium replaces calcium and magnesium ions on clay particles, dispersing the soil particles and decreasing soil permeability.

The salt content of soils is determined by the electrical conductivity (millimhos per cm) or percent of the soil mass in more severe conditions. Generally, when the conductivity rises to above 4.0 mmhos/cm, the salt content is considered high and will affect yields of all except salt-tolerant plants (Reference D-19).

Crops commonly grown in the Denver region will suffer 50 percent reduction in yield at a soil salt concentration of 0.25 percent (with 50 percent water saturation). Assuming a 1.2 m [4 ft]- root zone and a background salt level of 0.05 percent, 200 metric tons [200 tons] of dry solids would add the maximum limit of 0.20 percent more salt to the root zone (Reference D-1).

Low-rate application of sludge probably will not cause salt accumulation in amounts that would affect plant growth. For irrigated land, the leaching provided by the irrigation water should prevent a harmful buildup of salts. Crop yield would be reduced on dry land farms by lower salt concentrations that were not flushed by leaching. At loading rates of less than 1 m ton per year [1 ton/yr], over 100 years would be required to reach potentially harmful salt concentrations of 0.15 percent in the soil (Reference D-1). Salt accumulation in soils is easily monitored and can be controlled with proper management.

Boron is a potentially hazardous element, commonly viewed with alarm in irrigation waters. The most boron-sensitive crops are adversely affected at levels above 0.3 mg/l in the irrigation water. No limits have been established on the tolerable levels of boron in sludges; however, it is possible to compare boron loadings resulting from typical irrigation applications with equivalent applications of sludge. About 100 mg/kg of boron concentration in sludge, applied with recommended limits, can be considered a safe limit. Historical data on the boron concentration of sewage sludges in Denver do not exist. A recent grab sample analysis of the three Denver sludges produced the following boron concentrations:

Denver Central Plant Primary Sludge:	60 mg/kg
Denver Central Plant Waste Activated Sludge:	62 mg/kg
Denver North Side Digested Primary Sludge:	31 mg/kg

AGRICULTURAL CONSIDERATIONS

Fertilizer Value

Anaerobically digested sludge contains all of the essential plant nutrients and has valuable soil conditioning properties. The literature contains many references to increased plant growth resulting from the application of sludge. The major fertilizing elements, nitrogen, phosphorus and potassium, are present in varying proportions depending upon the nature of the sludge and other factors such as the length of time which the sludge has been dried or stored. Essentially, the solids portion of the sludge contains most of the nitrogen and phosphorus, while the liquid portion contains most of the potassium (Reference D-20). In calcareous soils, such as those found in the Denver area, potassium is more available to plants than in non-calcareous soils, and thus the low potassium content of dried sludge would probably not need to be supplemented by commercial fertilizer.

Total nitrogen content of air-dried sludge is approximately 6 to 8 percent of the dry weight, with about one-half of that present as ammonium nitrogen. It is assumed that approximately 30 percent of the total nitrogen in applied sludge is made available for plant use in the first year, 15 percent in the second year, 10 percent in the third year, and 5 percent in the fourth and succeeding years. Since nitrogen is usually considered to be the limiting factor in annual sludge application rates, sludge as a commercial fertilizer substitute can supply the needed amount of nitrogen for a particular site and crop. Other nutrients, such as potassium, may be deficient and require supplemental fertilization. Phosphorus (at 3 percent of the dry solids) is abundantly supplied in an application which is computed to balance nitrogen with uptake by plants. The possibility of applying excess phosphorus exists in non-calcareous soils.

Fertilizer Market

In 1972, 36,000 metric tons [40,000 tons] of fertilizer were sold in the Denver area, a large part of which was used for urban lawns, gardens and other non-farm purposes (Reference D-1). The 1970 farm fertilizer use percentage by crop and the total land area are shown in Table D-2. The main source of organic fertilizer in Colorado is livestock manure (88 percent), with about 10 percent of organic fertilizer sales consisting of sewage sludge (Reference D-1). Commercial sales of natural organic fertilizers have dropped off considerably in Colorado, but the amount of manure that is used for fertilizer far exceeds the amount which is sold commercially (Reference D-1).

The overall commercial fertilizer market adds perspective to the use of sludge in place of chemical fertilizers. Increased demands are being made on the fertilizer industry as a result of various factors, including the energy crisis, the need for heavier applications in old farming areas, and increases in newly added farming areas. Domestic supplies are predicted to fall short of the demand, and the increasing prices of commercial fertilizer may induce more farmers to view the use of sludge favorably.

The ability of sludge to compete with fertilizers in the marketplace is an issue that will certainly emerge in the near future. For example, at a trucking cost of \$0.08 per cubic meter-kilometer [\$0.10/cu yd-mile], a distance of about 100 km [60 mi] would represent the limit at which the transportation cost of air-dried sludge (with 5 percent nitrogen on a dry weight basis and 50 percent solids) equals the current price of equivalent commercial chemical fertilizer nitrogen (\$0.55 per kilogram [\$0.25/lb]) alone. A general formula for computing the break-even distance for trucking sludge is given simply by:

$$D = \frac{F\ N\ W\ S}{Y} \qquad \text{(Equation D-3)}$$

where D is distance from the distribution center to the ultimate application area, F is unit commercial fertilizer cost, N is fraction of nitrogen in the dry solids, W is the fraction of solids in the slude, S is specific weight of sludge and Y is cost of trucking a unit volume of sludge (including Water) over a unit distance, all parameters being in compatible (metric or English) units. Application cost is assumed equal for sludge and chemical fertilizer.

Crop Selection

Selection of crops suitable for growth on sludge-enriched soils should be done in consultation with the local extension service of the U. S. Department of Agriculture. Plants vary widely in their reactions to sludge application, and these reactions are site-dependent. Under most conditions, some crop species take up and accumulate certain trace elements, reducing crop yield and inhibiting use in the food chain. The major factors governing crop response on sludge amended soils are soil type, pH, moisture content, climate, and crop species. Soils that have a neutral or higher pH, a high cation exchange capacity and a high amount of organic matter reduce the availability of trace elements and their uptake by plants.

Crops that are grown for their seeds or fruits rather than vegetative

Table D-2. ON-FARM FERTILIZER USED IN DENVER AREA, 1970

Crop	Percentage of total element applied N	P	K	Hectares planted	Acres planted
Corn	51	12	-	32,684	80,700
Wheat	7	1	-	123,525	305,000
Sugar beets	23	50	28	8,829	21,800
Potatoes	1	3	16	830	2,050
Barley	10	19	-	33,453	82,600
Oats	2	2	-	14,418	35,600
Dry beans	0	1	7	4,617	11,400
Sorghum	1	1	11	3,657	9,030
Alfalfa	5	11	38	37,058[a]	91,500[a]
	100	100	100		
Total tons sold and surface area	4,003, metric [4,413, short]	1,187, metric [1,308, short]	110, metric [121, short]	259,070	639,680

[a] Harvested.

Source: Agricultural Reuse Program (Reference D-1).

tissue and crops whose younger rather than older vegetative tissue is utilized are more desirable in terms of trace element accumulation. Some crop species and varieties are more tolerant to trace elements than others. Field crops such as corn, small grains, and soybeans are moderately tolerant. Most grasses (fescue, lovegrass, Bermudagrass, orchard grass, perennial ryegrass) are tolerant to high amounts of metals. Unusually metal-tolerant ecotypes of the grasses are found on ore outcrops containing extremely high amounts of metals (Reference D-5). The leafy vegetables such as beets, mint, vine, lettuce, swiss chard, tend to accumulate cadmium and other heavy metals in their leaves.

The nutrient uptake potential of different crops is essential information for determining nitrogen loading rates, as discussed above under Nitrogen. Table D-3 presents nitrogen uptake by certain forage, field and forest crops. The varying capacities of different crop species to use water through evapotranspiration relate to the water regime of the area and possible salt accumulations in the soil. Daily consumptive water use of three crops grown near Denver is shown in Figure D-1.

The selection of vegetative cover can also influence the potential for contamination of surface waters, since certain plants stabilize the soils and control erosion and runoff more efficiently than others. For example, most grasses would be superior to crops such as soybeans or corn in the control of runoff (Reference D-20).

Germination

The inhibition of germination following the application of liquid digested sludge on soils has been occasionally reported. The results of two research efforts in this field are briefly presented below.

Molina, Braids, Hinesly and Cropper conducted experiments with corn and soybeans (Reference D-22). Seeds did not germinate in the liquid phase of fresh digested sludge. This inhibition was not due to ammonium nor solely due to a salt effect, an oxygen deficiency, or a low oxidation-reduction potential of the medium, they concluded. Seeds did germinate in digested sludge which had been aged in contact with the air for one week.

Sabey and Hart worked with sorghum sudangrass, millet and wheat, using Metro Denver sewage sludge (Reference D-19). They found that increasing amounts of sewage sludge caused increased inhibition of germination and emergence of sorghum sudangrass and millet when planted shortly after the sludge was incorporated into the soil. Wheat was planted five months later and did not show any inhibitory effects, even with high rates of application. A later greenhouse study (the results of which have not been completely analysed) shows that with low application rates (22 to 45 metric tons/hectare [10 to 20 tons/acre]), two

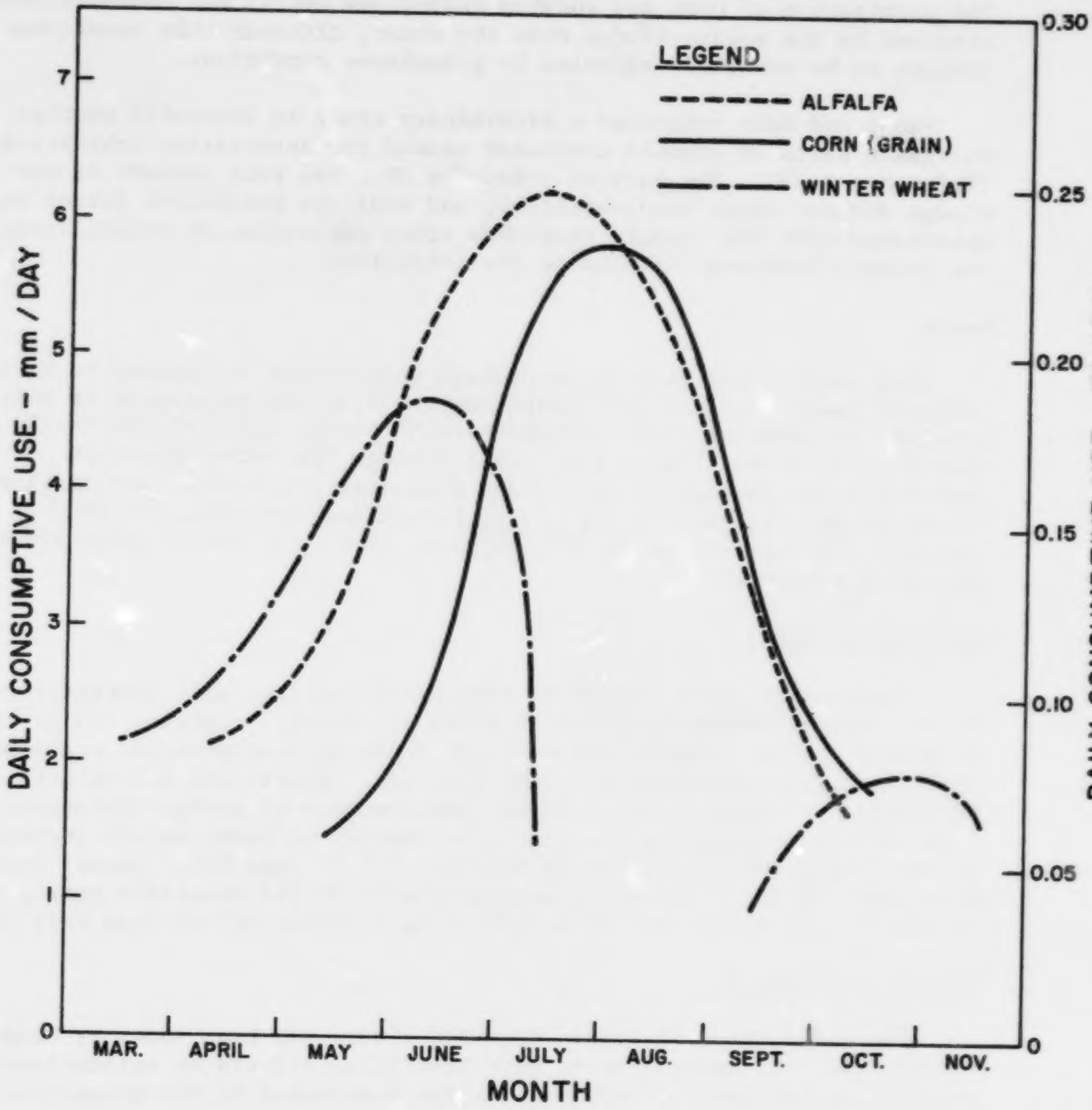
Table D-3. REPORTED NUTRIENT REMOVAL BY CROPS

Crop	Nitrogen uptake (kg/ha/yr)	Nitrogen uptake (lbs/ac/yr)
Forage		
Coastal Bermuda grass	538-672	480-600
Reed canary grass	253-402	226-359
Fescue	308	275
Alfalfa	174-246	155-220[a]
Sweet clover	177	158[a]
Red clover	86-141	77-126[a]
Lespedeza hay	146	130
Field		
Corn	174	155
Soy beans	105-127	94-113[a]
Irish potatoes	121	108
Cotton	74-112	66-100
Milo maize	91	81
Wheat	56-85	50-76
Sweet potatoes	84	75
Sugar beets	82	73
Barley	71	63
Oats	59	53
Forest		
Young deciduous (up to 5 years)	112	100[b]
Young evergreen (up to 5 years)	67	60[b]
Medium and mature deciduous	34-56	30-50[b]
Medium and mature evergreen	22-34	20-30[b]

[a] Legumes obtain a substantial part of their nitrogen requirements from the air.

[b] Estimated.

Source: Design Seminar for Land Treatment of Municipal Wastewater Effluents (Reference D-21).



SOURCE: AGRICULTURAL REUSE PROGRAM (REFERENCE D-1)

FIGURE D-1
DAILY CONSUMPTIVE WATER USE OF CROPS
GROWN NEAR DENVER, COLORADO

weeks to one month is sufficient to eliminate the inhibitive effects on wheat. The time period increases with higher rates of application. The germination of corn and sorghum sudangrass hybrid was somewhat more affected by the sewage sludge than the wheat, although this result was thought to be adversely affected by greenhouse conditions.

Sabey and Hart conducted a preliminary study to determine whether inorganic salts or organic compounds caused the germination inhibition (Reference D-19). The authors concluded that the salt content of the sludge did not cause the inhibition, and that the inhibitive factor is associated with the organic compounds since destroying or volatilizing the organic compounds eliminates the inhibition.

Weeds

Weed control may be a major problem when sludge is applied to agricultural land, although the literature contains few references to this problem. A cause of weeds associated with sludge applications is the viability of seeds of many food crops through the human digestive system and the wastewater and sludge treatment processes. Application of sludge may necessitate the use of herbicides for effective weed control. The concentration of herbicides in runoff and drainage water should be monitored.

Application Rates

Application rates depend on sludge composition, soil characteristics, climate, vegetation, and cropping practices. Applying cludge at an annual rate to support the nitrogen needs of a crop avoids problems associated with pollution of water supplies. Almost all ill-effects arise from too heavy or too frequent applications of sludge (Reference D-3). Total sludge application limitation is imposed by heavy metals content of the sludge and is defined by Equation D-1 on page D-5. Annual application rate, on the other hand, is constrained by the available nitrogen content of the sludge and is expressed in Equation D-2 on page D-11 above.

General Conclusions

The application of liquid digested sludge has been shown by research and by practical experience to have beneficial effects on agricultural lands if proper rates of application (as determined by the properties of the sludge, the nature of the site and the characteristics of the crops grown) are adhered to. These beneficial effects are generally the result of the enhancement of soil properties and the addition of plant nutrients that lead to increased crop yields. There are many references that document increases in plant growth as a direct result of the application of sludge. Some studies even show that yields are higher on sludge enriched soils than on soils which have received commercial fertilizer. (Reference D-23).

Although the application of sludge to a given area is extremely site dependent, some general conclusions which may be of use are presented below (Reference D-10, D-15, D-19):

1) Salt buildup in the soil can create a short term hazard to plant growth, but will not cause long-term problems if proper irrigation and drainage practices are followed.

2) Pathogenic dangers, as indicated by fecal coliforms, will not extend more than 120 to 150 cm (50 to 60 in.) into the soil profile, nor last more than 2.5 months near the soil surface.

3) Heavy metal contamination of the groundwater is not a problem even at high sludge loadings because of the soil's ability to adsorb and retain them. Cadmium may be the first metal to present such a problem (Reference D-15).

4) Heavy metal uptake by plants grown on sludge amended soil is not expected to be excessive and should cause no plant toxicity or human dangers as long as the ultimate application rate limit is not exceeded.

5) Nitrate leaching to the groundwater can be substantial, increasing directly with sludge application rates, and will be the first limiting factor for sludge application on a yearly basis.

6) Nitrate leaching can be controlled with management techniques involving balancing nitrogen applications with crop uptake.

7) Potential hazards to the groundwater can be more accurately monitored by measuring leachate quality and quantity than through direct groundwater sampling.

8) Direct ingestion of sludge-applied soil by domestic animals can be a potential danger to the human food chain through direct accumulation of heavy metals in edible tissues.

9) Seed germination can be inhibited if sludge is added just prior to planting. If planting is conducted two weeks to one month after sludge application, seed germination is uninhibited.

10) Properly digested sludge will produce no offensive odors after application and incorporation into the soil.

11) A sound agronomic and environmental principle is to apply the least amount of sludge that will supply sufficient nutrients for plant growth.

12) Monitoring is necessary for sludge application programs to ensure against creating environmental hazards.

CHEMICAL PROPERTIES OF METRO DENVER SLUDGE

The organic material generated by the Metro Denver Sewage Disposal District No. 1 will be anaerobically digested, and will contain organic and inorganic nutrients, humus, and residual levels of various metallic compounds. The digested sludge will contain 6 to 8 percent total nitrogen (expressed as a percentage of the dry weight of the organic materials), of which 3 to 4 percent (of the total dry solids) will be ammonia nitrogen. The sludge will contain approximately 3 percent total phosphorus.

The most recent heavy metals concentrations of primary and waste-activated sludges from the Northside and Central treatment plants are presented in Table D-4. A flow-weighted average concentration is also computed and presented for the mixture that would result from blending these sludges. A comparison of the quality of this mixture with that of a "good" sludge is presented in Table D-5.

It can be seen that nickel and copper exceed the suggested limits. Excessive levels of these two heavy metals can adversely affect plant growth. The cadmium/zinc ratio, which is perhaps the most important indicator of heavy metal toxicity, is higher than the suggested limits. However, with the conservative application rate recommendations and the calcareous nature of soils in the study area, it probably will not cause a significant problem.

Metro Denver sludge contains all of the essential plant nutrients and possesses soil conditioning properties. The nitrogen content is satisfactory for fertilization purposes. The longer sludge is dried, the more ammonium nitrogen is lost through volatilization.

LAND USE OPTIONS FOR SLUDGE APPLICATION

Four specific land use areas are being considered by Metro Denver for the application of sludge. These are: 1) city parks, 2) mine spoil sites, 3) sod farms, and 4) irrigation and dryland farms. In this section, specific parameters will be discussed as they relate to each land use.

City Parks

The literature contains general references to the application of sludge on city parks, lawns and golf courses, but no definitive studies have been reported. In New York City, sludge has been used as a soil conditioner to produce artificial topsoil on proposed park sites (Ref-

Table D-4. SLUDGE HEAVY METALS CONTENT COMPUTED FROM SAMPLES OBTAINED AND ANALYZED OVER A PERIOD OF FOUR MONTHS IN EARLY 1975

	Heavy metals content, mg/kg dry sludge		
Parameter	Primary sludges[a]	Concentrated waste-activated sludges[b]	Flow-weighted average[c]
Zinc	927	1,252	1,145
Copper	587	916	808
Nickel	268	289	282
Chromium	301	545	465
Lead	275	383	347
Cadmium	9	24	19
Manganese[d]	131	97.5	109
Mercury[e]	17.8	4.2	8.7
Cd/Zn ratio	0.0065	0.019	0.017

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[a] Arithmetic averages computed for 18 samples except for manganese and mercury (see footnotes d and e, below).

[b] Arithmetic averages computed for 17 samples except for manganese and mercury (see footnotes d and e, below).

[c] It was assumed that the mixture contains 33 percent primary and 67 percent concentrated waste-activated sludge.

[d] Arithmetic averages computed for two samples.

[e] Arithmetic averages computed for three samples.

Source: Raw data obtained from Metropolitan Denver Sewage Disposal District No. 1.

Table D-5. COMPARISON OF METRO DENVER SLUDGE HEAVY METAL CONTENT WITH SUGGESTED LIMITS

(mg/kg dry solids)

Element	Existing concentrations	Suggested limits (Reference D-24)	Suggested limits (Reference D-13)
Zinc	1,145	1,500	2,000
Copper	808	750	800
Nickel	282	150	100
Chromium	465	500	-
Lead	347	500	1,000
Cadmium	19	50	< 0.5 % of zinc
Manganese	109	-	-
Mercury	8.7	-	15
Boron	51[a]	-	100
Cadmium/zinc ratio	0.017	0.001 - 0.005[b]	0.005

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[a] Obtained by computing a sludge solids flow-weighted average of grab samples described on page D-15. Grab samples were collected on 30 October 1975.

[b] Reference D-13.

erence D-11). Composted sludge and leaf mold are being used to renovate the soil at the newly created Constitution Gardens in Washington, D.C. (Reference D-25). Liquid and possibly dewatered sludge can be applied to the surface of turf grass, but odor might be a problem and time would be required before traffic could be allowed to return (Reference D-14). The timing of sludge application could control the odor problem. If sludge is applied in the winter, the snow and moisture will carry the nitrogen value to the root zone, will eliminate any perceptive odor, and will accelerate lawn growth in the spring (Reference D-26).

In general, grass is a good crop for sludge fertilization because it is tolerant of heavy metals, has a high rate of nitrogen uptake, and minimizes problems from runoff. Furthermore, with each cutting appreciable quantities of salts and nutrients are removed from the land, if only to be placed in landfills.

Mine Spoil Sites

The literature contains many references to the use of sewage sludge for revegetation programs on mine spoil sites. Most of these sites have been coal mine spoils, although the extreme environmental conditions associated with coal mine spoil sites are generelly similar to those of other large scale mining operations. In general, problems result from extremely acid soil conditions, high rates of erosion and runoff, acidic runoff, toxic levels of certain metals in the soil, low soil fertility, low soil moisture content, and high summer surface temperatures. Because of the nature of mining operations, spoil sites necessarily do not possess a substrate favorable to plant growth. Most soils evolve over long periods of time as a result of weathering of parent material and the accumulation of organic matter.

Experiments with revegetation of spoil sites have confirmed the difficulty of establishing vegetative cover on such harsh conditions. There is frequently 100 percent mortality of plants on spoil sites with no amendment. On sites treated with sludge, plants germinate and survive.

The potential toxicity of a mine spoils site is best characterized by the pH. Although there is a difference in plant tolerance to acidity, a spoil material with pH below 4.0 is toxic to most plants. The pH of most spoil sites is between 2.0 and 3.0. At these values the high solubility of certain metals such as iron, aluminum and manganese severely inhibits plant growth. Evans and Sopper report that on an experimental plot, the untreated control boxes had complete mortality of trees, grasses and legumes. They also had the lowest average values for phosphorus and nitrate-nitrogen and the highest values of iron, manganese and aluminum. Plots treated with effluent and sludge, had the highest values for phosphorus and nitrate-nitrogen and the lowest for iron, manganese and aluminum. Since benign spoil materials are also low in soluble phosphorus and nitrate-nitrogen, they concluded that iron, manganese and aluminum are more directly related to revegetation failures. The higher concentrations of these and other heavy metals appear to be the results of solubilization of the native rock by the high acidity. Irrigation with effluent and sludge leached and diluted the native salts (Reference D-27). The addition of sludge also increased both phosphorus and potassium levels in the treated spoil (Reference D-28).

The establishment of a complete ground cover of vegetation is highly desirable since it can result in (1) earlier stabilization and reduction of erosion; (2) earlier mitigation of acid drainage by diminishing net recharge through increased evapotranspiration losses; (3) the acceleration of accumulation of organic residues which will chelate and otherwise make unavailable the soluble iron, manganese and aluminum (Reference D-27). Organic residues also provide the necessary seed bed for plant germination.

The major effects of the application of digested sludge to mine the spoil sites include the improvement of spoil pH, increased infiltration of precipitation, the germination and establishment of vegetation, and the reduction of acidity and concentrations of some of the chemicals in the runoff issuing from the site (Reference D-29).

Sod Farms

The use of digested sludge on sod farms has been proposed by Metro Denver and some of the sod growers in the Denver Area. Sludge contains all of the essential plant nutrients and enhances soil properties through the addition of organic residues. Sod farming involves the periodic removal of the topmost plant and soil layers, thus the importance of the ability of sludge to provide continuing soil-building material becomes apparent. Site conditions regulate the application rate of sludge, depending on specific soil and crop characteristics. Grass is a good crop for sludge fertilization because it is tolerant of heavy metals, is not used as feed or food, has a high rate of nitrogen uptake, and minimizes problems from runoff and erosion. If sludge is applied in the winter, the snow and moisture will carry nitrogen to the roots, will eliminate any perceptive odor, and will accelerate vegetative growth in the spring (Reference D-26).

Irrigation and Dryland Farms

Digested sludge has been used widely in agriculture throughout the United States and in other parts of the world. Most of the material discussed in this appendix relates to the agricultural use of sludge and need not be repeated. In general, dry farmland will sustain a lower application rate of sludge because the rate of nitrogen uptake of dryland crops is much lower than that of irrigated crops. Most irrigated and non-irrigated crops grown in the study area are either not consumed by humans or are processed to such a degree that sludge contaminations are removed.

Irrigated crops include many plants intended for direct human consumption with minimal processing. Even though it is not recommended to apply sludge on fields growing such crops, proximity of the various fields, rotation patterns and loss of records may lead to inadvertent sludge contact with these plants. Therefore, a greater degree of importance should be attached to control and management recommendations to mitigate adverse impacts on the food chain.

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The discussion of environmental setting, presented in Section III is supplemented in this Appendix with a detailed study of site-specific environmental characteristics. The sites discussed here include the drying and distribution site, the representative sludge reuse sites (city parks, sod farms, mine spoil sites, irrigated farms and dryland farms), and the site of the existing operations at the Lowry Bombing Range.

APPENDIX E

ENVIRONMENTAL SETTINGS OF DRYING AND DISTRIBUTION SITE AND SPECIFIC LAND APPLICATION SITES FOR METRO DENVER SLUDGE

DRYING AND DISTRIBUTION SITE

The proposed drying and distribution center, Site B-2, is located about 32 km [20 miles] east of the District's Central Plant. As shown on Figure 2, it is 18 km [11 miles] southeast of Barr Lake and is bordered on the south by Irondale Road. The site is rectangular, extending about 2.4 km [1.5 miles] in an east-west direction and 3.2 km [2 miles] in a north-south direction. The description of the environmental setting of the drying and distribution site is taken from "Metro Denver Sludge Management, Volume IV, Environmental Assessment," by CH2M-Hill (February 1975).

Topography

The topography of the project area is slight to moderately rolling slopes. Elevation of the terrain ranges from approximately 1,570 m to 16,40 m [5,150 ft to 5,390 ft] above sea level. There is a slight ridge running north-south through the center of the site. The view to the north from Irondale Road is generally unobstructed by topographic features up to the ridge in the midpoint of the site. A pronounced drainageway occupies the southeastern corner of the site.

Soils

The soils at the site are in general a tight, silty clay material and have a low permeability rate compared to many soils in the area. Soil depths have not been determined in the area of the site. These soils have sufficient organic materials, with satisfactory nutrient levels, for most crop production. Low crop yields in the area can generally be attributed to low rainfall.

Surface Water

The project site has no perennial streams or other water bodies. The site is on high ground and receives runoff only from within the site. A natural drainage area in the southeastern corner of the site subjects a small off-site area to surface inflow and possible flooding.

Part of the site is subject to severe water erosion problems as a result of high-intensity, sudden thundershowers and snowmelt on unprotected soils. The runoff is high in sediment and suspended solids.

Groundwater and Geology

The project area is underlain by the Denver-Arapahoe-Dawson formation and the Laramie-Fox Hills formation. Each of these formations yields a small to moderate supply of water to wells for domestic and livestock uses. The uppermost bedrock is the Denver or Arapahoe formation. Both formations are composed of layers of shale, sandstone with some clay, and silt stone. The aquifers in these formations are more or less confined, and vertical permeability between water-bearing zones does not occur readily. The Laramie-Fox Hills formation underlies the site at an estimated depth of 270 to 400 m [900 to 1,300 ft] and is considered the boundary between fresh water and brackish water. Available resource information indicates that the water above the Laramie formation is of good quality.

The depth to groundwater on the site is typically 15 m [50 ft] or more, with upland wells having a water depth of 30 m [100 ft] or more. No groundwater was encountered in the top 3 to 4 m [10 to 12 ft] during exploratory investigations with a backhoe. The exact size and yield of aquifers underlying the site is not known.

Biology

Vegetation--

Wheat crops are rotated on the project site, leaving 50 percent of the crop area fallow each year. Within the southeastern corner, the site has a 1.6-hectare [4-acre] area of overgrazed prairie. The site has no trees or shrubs. Vegetation consists of short grasses (blue grama, western wheat and buffalo), yucca, Russian thistle, wild lettuce, sunflower and prickly pear cactus. No rare or unique species of vegetation considered essential to the ecology of the region are present on the site.

Wildlife--

Wildlife studies did not identify any wildlife habitats essential to the site's ecology. In the general vicinity of the site, there are varying species of rabbit, mouse, owl, hawk and coyote. Except for the coyotes, which are territorial animals, these species do well in disturbed areas. There is sufficient area surrounding the site to provide new habitats for animals displaced by construction.

Air Quality

Air quality in the vicinity of the project area is relatively good.

The site is sufficiently removed from the Metropolitan Denver area to be unaffected by the urban pollution problem. The only significant deterioration of air quality in the area occurs during dust storms. The severity of these depends on conditions of wind, precipitation and soil disturbance such as plowing. Even at its worst, however, wind-blown dust does not constitute a major problem in the area.

CITY PARKS

The City of Denver has developed an elaborate park system. More than 100 named parks, and many interconnecting landscaped parkways, cover more than 1,100 hectares [2,800 acres] within the city limits. The topography of Denver is relatively flat, with an elevation ranging from about 1,570 to 1,670 m [5,150 to 5,480 ft]. Two perennial watercourses, the South Platte River and Cherry Creek, flow through the city. Many lakes have been created, most of which are included within the City park system and are utilized for recreation. The lakes are discussed under General Environmental Setting, above. They are significant with respect to runoff hazards from sludge applied to park areas surrounding them.

Soils

The soils in the City and County of Denver have not been surveyed for agronomic purposes because of the predominantly nonagricultural land use in the metropolitan area. Therefore, detailed information about these soils is unavailable. The information presented is thus surmised from the general surface geology and soil conditions of the surrounding counties, augmented with limited site observations.

It is assumed that soils in the City parks are generally low in clay content (loams, silt loams, sandy loams and possibly some dry loams), with correspondingly low cation exchange capacity. Most of the soils are probably calcareous, beginning at some depth below the surface, if not found throughout the profile. Because of the necessary grading and leveling activities, most of the profiles are probably substantially altered, and most of the topsoil has been moved from one place to another. Of the more than 100 established parks in Denver, most are on subsoils of heavy clay "plated" with a thin layer (7.5 to 10 cm [3 to 4 in.]) of imported topsoil. Some 15 to 20 parks are planted on old landfills with a fine cover of topsoil.

Biology

Vegetation--

The vegetation of the City parks can be characterized generally as urban landscaping and has been described above, under Urban/Residential Unit. With the exception of the two stream courses traversing the city, the site of Denver was originally part of the mixed prairie, but a variety of nonnative trees has been planted along the streets and in the parks. Chief among these trees are soft maple, elm, weeping willow, Carolina poplar, Lombardy poplar, ash, sycamore, Norway pine, Russian olive and several varieties of fruit trees. The City park system is entirely artificial, with extensive lawns, gardens, shrubs and trees having been planted on graded, leveled and filled areas. Many of the parks include golf courses with extensive areas of grass.

Some nearby urban communities with extensive park sites, such as Northglenn, Commerce City and Aurora, have expressed interest in applying sludge to their City parks, also.

Wildlife--

The urban and residential environs of the Denver Metropolitan area represent a unique, though unnatural, environment. The introduction of nonnative shrubs, herbs, grasses and trees has incidentally selected and attracted many animal species that normally would not occur in this area.

Chief examples of such introductions are the red-eyed vireo, bronzed grackle, robin and house sparrow. Some species are typically introduced with urbanization and become established as pests which destroy food and property or endanger public health. These "undesirables" include the starling, house mouse, Norway rat and, in some cases, the pocket gopher.

A woodland-type atmosphere has been created by planted groves of trees within many of the City parks. Native species which can adapt to human presence include the black-capped chickadee, house finch and chipping sparrow. Occasionally several bat species may also be found within the trees. The large expanses of grass within the City park system and golf courses particularly attracts robins and starlings.

Noise

The Denver Metropolitan area has many noise sources and attendant noise pollution similar to that found in all large cities. In the residential areas, transportation systems are the most noticeable sources of noise. Generally, the extensive City parks are bounded and traversed by multi-laned streets and expressways. Steady automobile traffic produces ambient noise levels of 60 to 95 decibels. Particularly abrasive noises greater than 85 decibels are generated by trailer trucks, motorcycles and sports cars (Reference 89).

Within the urban and residential areas, noise sources are regulated by speed limits and designation of traffic corridors. Thus, residences and community facilities are somewhat screened from extreme noises. Trees and shrubs in the residential areas, particularly in the patchwork City park system of Denver, reduce sound levels to some degree. The presence of decorative plantings, although they do not significantly reduce noise levels, often have the effect of reducing the incidence of complaint about noise (Reference 89).

Odor

At the present time, odors in City parks are determined by particular local neighborhood activities (industrial emissions in certain parts, poorly controlled exhaust from stationary and mobile sources in other parts and temporary odors caused by applications of chemicals to lawns and trees, etc.). City park and public works crews attend to the cleanliness and maintenance of the park areas. Overall, under most conditions, there are no noticeable disturbing odors present at City parks where large numbers of people spend a great deal of time walking, sitting, lying on the grass, eating lunch and engaging in sports activities.

SOD FARMS

Sod farms represent a special type of irrigated farm. Many hectares in Adams and Weld counties, as well as in other areas south of Denver, are used for this grass culture. Sod farms yield one of the major nonconsumptive crops in the area. The sod is used solely for landscaping and decorative plantings. Sod farms typically require warm, sunny weather, frequent irrigation and heavy fertilization.

A representative sod farm was examined in Adams County and is shown in Figure E-1. The farm is located near Brighton, east of Barr Lake. It is owned by Bill Mathews and includes areas in Sections 25 and 26, T.1.S, R.65W. Elevations vary gradually.

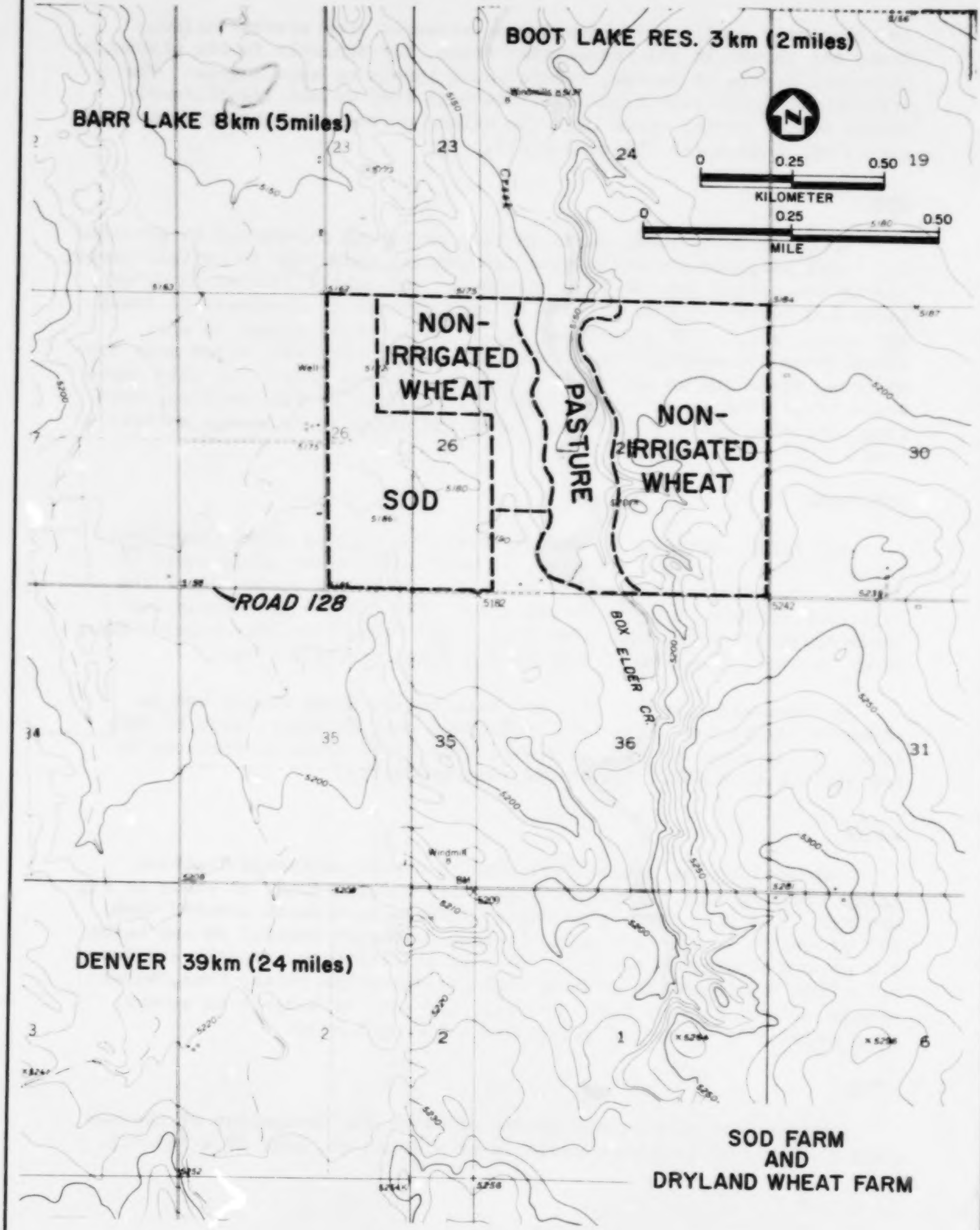
Soils

The soil in the Mathews sod farm is nearly uniformly Trackton loamy sand, on nearly level to moderately sloping land, as shown on Figure E-2. The soil texture is rather uniform to a depth greater than 150 cm [60 in.]. It is a noncalcareous soil with neutral pH and rather low cation exchange capacity. The soil absorbs water rapidly and does not allow runoff except at very high precipitation rates; thus, water erosion hazard is very low. However, the soil is subject to severe wind erosion if it is not stabilized with vegetation.

Water

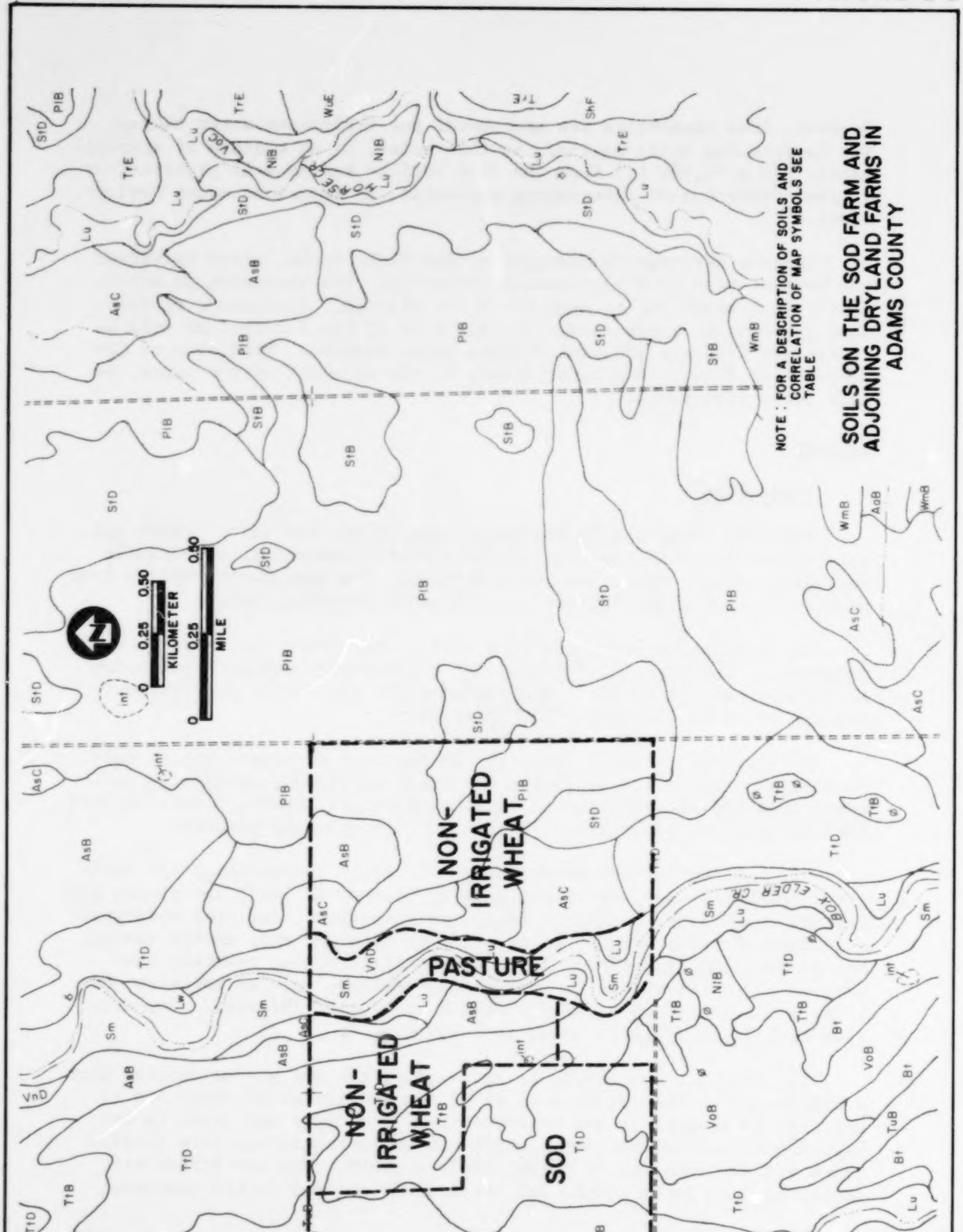
Groundwater is the only source of water for irrigation of the sod farm studied. Groundwater table is at a depth of about 20 m [60 ft].

FIGURE E-1


BOOT LAKE RES. 3 km (2 miles)
BARR LAKE 8km (5miles)
0
0.25
0.50
KILOMETER
0
0.25
0.50
MILE
23
23
24
19
Creek
Windmills
Well
NON-IRRIGATED WHEAT
PASTURE
NON-IRRIGATED WHEAT
26
26
SOD
30
ROAD 128
BOX ELDER CR.
34
35
35
36
31
Windmill
5200
5250
5300
DENVER 39km (24 miles)
3
2
2
1
6

SOD FARM
AND
DRYLAND WHEAT FARM

FIGURE E-2


NON-IRRIGATED WHEAT
PASTURE
NON-IRRIGATED WHEAT
SOD
KILOMETER
0
0.25
0.50
MILE
0
0.25
0.50
N
HORSE CR
BOX ELDER CR
StD
PlB
AsB
AsC
StB
TtB
TtD
TuB
Lu
Lw
Sm
VnD
VoB
VoA
NlB
Bt
WmB
AoB
TrE
WuE
ShF
VoC
int

NOTE: FOR A DESCRIPTION OF SOILS AND CORRELATION OF MAP SYMBOLS SEE TABLE

SOILS ON THE SOD FARM AND ADJOINING DRYLAND FARMS IN ADAMS COUNTY

However, deep reservoirs are pretreated for irrigation water supply. The Laramie-Fox Hills aquifer, at this point, is at a depth of approximately 370 m [1,200 ft] from the land surface and is well protected by a great thickness of intervening aquitards, as described under Geology, above.

Surface drainage is provided by Box Elder Creek, which traverses the Mathews farm in a north-south direction. The streambed is dry nearly year-round and is used for a cow pasture. (The owner of the farm proposes to apply sludge to this part of his farmland as well as to the sod farm and adjacent dryland wheat fields.) Frequency of occurrence of flow in Box Elder Creek, by the estimate of the owner, is once every five years.

Biology

Vegetation--

Kentucky bluegrass is the basic crop of the sod farm. Thick sod mats formed by this grass constitute a stable community, effectively excluding other competitive plant species. The crop period varies from nine to 18 months and follows the procedure described below:

1. Seed bed preparation--The fields are plowed and graded where necessary. Chemical fertilizers with a nitrogen-phosphorus-potassium (N-P-K) percentage of 16-16-8 or 18-46-0 are applied to the prepared surface at up to 110 kg/ha [100 lb/acre].

2. Seeding--Several varieties of Kentucky bluegrass may be used. Particular strains may be chosen for their hardiness, ability to withstand cold and adaptability to local conditions. Common blends include merion, windsor, pennstar, fylking, baron, nugget and newport.

3. Cultivation and maintenance--The newly planted beds are irrigated frequently for the first three to four weeks until the plants are set and a sod layer begins to form. At this stage, the crop undergoes a regimen of spray irrigation as often as once per day, weekly mowing and monthly fertilization. Chemical fertilizers most commonly used have an N-P-K percentage of 20-20-10 or 16-16-8, such as ammonium sulfate, and are applied typically at 335 kg/ha [300 lb/acre]. Comparative fertilizer usage is shown in Table E-1.

4. Crop harvest--Prior to harvesting, the sod may be treated with a high-nitrogen fertilizer such as 46-0-0 and irrigated every one to two days to prepare it for transporting. The upper sod layer is harvested with special machines, which cut an approximately 5-cm [2-in.] thick sod and soil mat of 45-cm [18-in.] width. The sod strips are rolled up into large rounds and immediately shipped to the customer.

Table E-1. COMPARATIVE FERTILIZER USAGE AT SELECTED SOD FARMS IN THE DENVER REGION

Farm	Fertilizer type,[a] N-P-K	Application rate, kg/ha[c]	Application frequency, times per year	Maximum nitrogen application rate,[b] kg/ha	Crop cycle, months
A	20-20-10	225	7 to 8	335	12
B	16-16-8	335	7 to 8	705	9 to 12
	46-0-0	450	1 to 2		
C	18-46-0	110	1	315	18
	33-0-0	225	4		
D[d]	5-3-3	1,900	1	450 to 840	14
	5-3-3	1,455	7 to 8		
	32-0-0	450	1		
E[e]	20-20-10	335	4	270	18

[a] Fertilizer composition expressed as percentage of nitrogen, phosphorus and potassium (N-P-K) in the total mixture.

[b] Nitrogen is calculated as N, assuming maximum amount and number of applications per year.

[c] 1 kg/ha = 0.893 lb/acre.

[d] Farm D utilizes dried poultry wastes as primary fertilizer.

[e] Mathews farm used as representative sod farm.

Source: References 90,91,92,93,94.

As the cut sod does not store well, it is usually cut the day prior to shipping. The harvest period varies from 9 to 18 months. Vegetative growth is most active during the spring and summer and slows considerably as the weather becomes colder. During the winter months, the grass enters a period of dormancy requiring little irrigation or fertilization. This resting period is necessary for future grass growth. The type of grass species and length of winter dormancy determine, to a great degree, the cropping period. Sod crops can also be regrown from the trimmed sod. When the demand is low, the sod crop--unlike consumptive products--can remain on the ground to be harvested at a later date without deterioration of quality.

Wildlife--

A sod farm represents a greatly simplified ecosystem of short grass and sod. Wildlife is generally dominated by a few species, which are seasonal in occurrence. In the planting stage, seed-eating birds such as Brewer's blackbird and the western vesper sparrow are common. As the crop growth progresses, earthworms, grasshoppers and their predator, the western meadowlark, proliferate. Small grass-eating and burrowing animals are less common in a sod farm compared to other cultivated fields. This is due to the constant mowing and maintenance, which disturb the animal habitat. Mammal species which may be found in the vicinity of sod farms are the pocket gopher, meadow vole and jackrabbit.

Noise

The countryside is generally noted for its quietude. The vastness of the plains area and generally open conditions allow for rapid noise dispersal. The main sources of noise pollution are trucks and automobiles travelling on the roadways crossing the plains region as well as farm equipment and machinery. Farm equipment is generally heavy duty and can generate noise levels equivalent to a truck-trailer. However, the relatively low density of farms and their remoteness make this noise source insignificant in the overall context.

Odor

There are usually no noticeable odors on a sod farm except immediately after mowings. These are pleasant and temporary smells confined to the immediate area of the mowed fields.

MINE SPOIL SITES

The Climax molybdenum mine, used as an example of mine reclamation, is situated in the Colorado Front Range approximately 80 km [50 miles] west of Denver. The location of the mine and tailings pond is shown in Figure E-3. The mine site is reached via U.S. Highway 40 and is approximately 6 km [3.7 miles] southwest of Berthoud Pass and 3.4 km [1.9 miles] south of the Continental Divide. The terrain is rugged and mountainous and is transected by deep canyons. The Urad mine and spoils site is located in the narrow canyon of Woods Creek, which is a tributary to Clear Creek. The Henderson mine and spoils site is located in the upper section of the west fork of Clear Creek. Elevation at the site is approximately 3,100 m [10,400 ft] above sea level.

The mining operations are conducted by Climax Molybdenum. The molybdenum-rich ore is mined from 900 m [3,000 ft] below the surface. The ore is crushed and washed in an acid solution to extract the metal, which is further refined. The residual rock material is finally deposited in the large tailings near the foot of Woods Creek Canyon and Upper Clear Creek Canyon. Leachates from the tailings are further collected downstream in a settling pond before entering Clear Creek.

The mine spoils areas are wedge shaped and cover approximately 60 ha [140 acres] to a depth of 75 m [250 ft]. The rock material on the site is coarse monzonite, only 16 percent of which passes through a 2 mm sieve. The final surface of the spoils site has been leveled to prepare for reclamation with sludge and wood chips and for plantings. At the present time, 6 ha [15 acres] have undergone initial reclamation and another 50 ha [125 acres] await reclamation.

Climax Molybdenum anticipates reaching full capacity at the Woods Creek Canyon spoils site by 1980. At that time, a new site will be used for tailings, and the old site will be available for full reclamation. By the year 2030, the ore at this particular site will probably be depleted, and the operations will be transferred to a site near Leadville, 190 km [120 miles] from Denver.

Climate

Located near the crest of the Continental Divide, the mine site experiences some extremes in climate, as shown in Table E-2. The mean annual temperature is less than 0°C [32°F], and mean temperatures are below freezing for six months per year. The growing season is relatively short, extending from one to two months in duration. Precipitation is heavy. A great deal of the precipitation occurs as snowfall. Snowfall amounts to more than one meter [3.3 ft] for at least six months per year, with the period from June to September being the most clement.

Geology

The mine spoil site is located on landslide deposits from the pre-Cambrian Silver Plume Granite and the Tertiary Porphyritic Rhyolite. Samples from the spoil site show that the tailings themselves are from the Silver Plume Granite. Most of the tailings are composed of porphyritic quartz monzonite veined with molybdenite and pyrite. Some pegmatite with large grains of molybdenite also make up part of the tailings.

FIGURE E-3

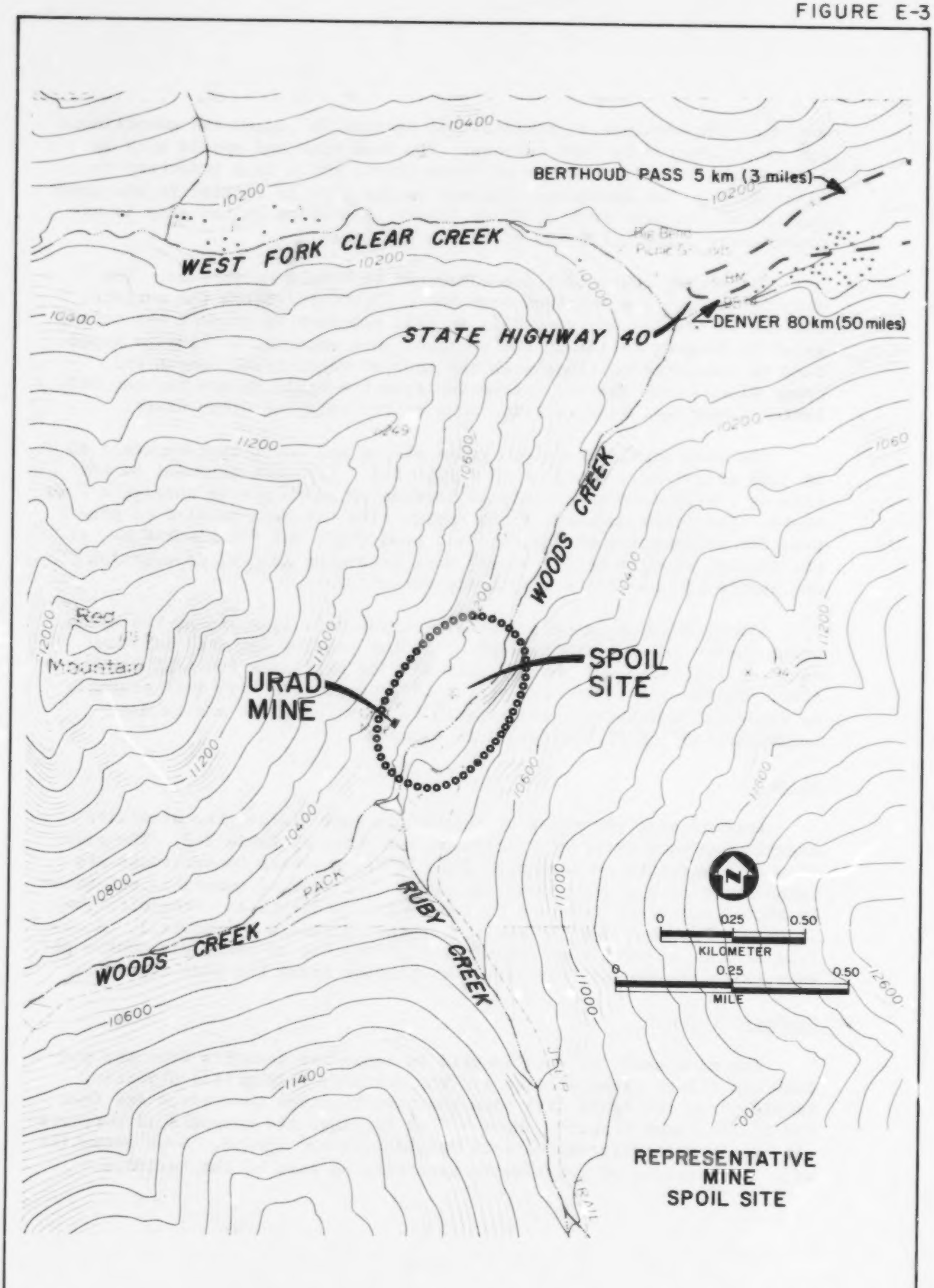

10400
BERTHOUD PASS 5 km (3 miles)
10200
10200
WEST FORK CLEAR CREEK
10200
10400
10000
DENVER 80 km (50 miles)
STATE HIGHWAY 40
10200
11200
10600
WOODS CREEK
10400
Red Mountain
12000
11000
SPOIL SITE
URAD MINE
11200
10600
10400
10800
PACK
RUBY CREEK
11000
WOODS CREEK
11000
10600
11400
0 0.25 0.50 KILOMETER
0 0.25 0.50 MILE
12600
TRAIL
REPRESENTATIVE MINE SPOIL SITE

Table E-2. TEMPERATURE, PRECIPITATION, SNOW AND FREEZE DATA, BERTHOUD PASS

											Nov	Dec	Annual
Temperature													
°C	-11.4	-11.4	-8.4	-4.4	1.6	5.7	10.4	9.1	5.3	0.6	-6.2	-9.1	-1.5
[°F]	11.5	11.4	16.8	24.1	34.8	42.3	50.8	48.3	41.6	33.0	20.8	15.6	29.3
Precipitation													
mm	72.9	73.2	91.7	108.5	84.6	73.4	72.9	63.0	58.2	55.1	73.7	94.5	921.5
[in.]	2.87	2.88	3.61	4.27	3.33	2.89	2.87	2.48	2.29	2.17	2.90	3.72	36.28
Snowfall													
cm	110.2	112.5	134.6	144.5	80.8	41.7	0	0.8	23.9	65.0	112.3	125.5	951.7
[in.]	43.4	44.3	53.0	56.9	31.8	16.4	0	0.3	9.4	25.6	44.2	49.4	374.7

Freeze threshold temperature °C	Freeze threshold temperature [°F]	Mean number of days between date of last spring occurrence and first fall occurrence
0	32	41
-2.2	28	64
-4.4	24	90
-6.7	20	118
-8.9	16	137

Source: Decennial Census of United States Climate; Climatological Data for the U.S.: Colorado.

Both molybdenite (MoS_2) and pyrite (FeS_2) are sulfides whose oxidation leads to acidic mine drainage. Without alterations and amendments, these rocks can be expected to provide an inhospitable substratum for plant growth.

Soils

There are no soils in the mine spoil site under study; nor would there be any developed soils at any other such sites destined for reclamation. The material involved in reclamation is processed rock, extracted from great depths, largely unaffected by soil-forming factors. At the Urad and Henderson mine sites, the spoil materials are very coarse (from gravel to boulder-size primary particles), are angular and are incapable of supporting plant life. Due to the acid treatment for extraction of molybdenum, these rocks can be expected to retain an acidic reaction for several years. Any reclamation scheme would necessarily require a change in the texture of the surface material in addition to introduction of organic matter and fertilizer elements.

Water

Tributaries to Clear Creek, i.e., Woods Creek and the upper section of the west fork of Clear Creek, flow along the mine spoil sites studied. Because of the exposed bedrock and occurrences of very thick consolidated rocks in the area, groundwater is of minor significance. Large holding basins in the mining areas are used to settle the fine particles suspended during processing of the rocks. Effluent from the ponds is discharged directly to the streams draining into Clear Creek.

Biology

Vegetation--

The vegetation on the mine spoil site is quite sparse, mainly because of the lack of soil. A thin layer of sludge mixed with wood chips and bark has been applied, and systematic planting of spruce, pine, juniper and aspen seedlings has been conducted. Some grass has also been seeded, and a few other native plants, such as yarrow, big sagebrush, bear berry and buffalo berry, have established themselves with the germination and growth of a few individuals. All of the vegetation on this site is growing very slowly, and some of it, such as the buffalo berry, appears stunted. Some of the tree seedlings have died.

Wildlife--

The mine spoils site is a severely disturbed area with very sparse plant growth, as described above. The exposed strata of rock and gravel provide a relatively sterile environment with no resident animal species. Visitants from the neighboring lodgepole pine forests may include mule deer, coyote, striped skunk, mountain vole and snowshoe hare. Probable bird species passing over the area are Cooper's hawk, turkey vulture, gray jay and gray-headed junco.

Noise

The mine spoils site is rural and fairly isolated. Traffic along Highway 40, which is 1.6 km [1 mile] away from the site, represents a small fraction of ambient noise. The main source of noise is from the processing of the ore. The rock-crushing and washing apparatus probably generate the most noise, while the small but steady truck traffic to and from the site augments the background noise levels. The relative isolation, heavy growth of trees adjacent to the site and steep valleys effectively confine the noise from the mining operations.

Odor

The molybdenum mine has few associated odors. On the limited tailing areas where reclamation has begun, some odors uncommon to the area are generated. The weathering of wood chips and sludge into the upper rock material exudes a faint decomposition odor at close range. However, the material deodorizes rapidly, and no odors are perceptible 30 m [100 ft] from the site.

IRRIGATED FARMS

There were almost 17,000 hectares [42,000 acres] of irrigated farms in Adams County in 1973 (Reference 95), about five percent of the whole county. By contrast, only about 900 hectares [2,200 acres] are irrigated in Arapahoe County (Reference 14), less than one percent of the county. Areas of irrigated crops and value of all crops grown in Weld, Adams and Arapahoe counties are presented in Table E-3. The proportion of irrigated land increases from south to north due to increased availability of surface and groundwater supplies. In Adams County, most of the irrigated farms are along the South Platte River and its tributary creeks. Water is directed from these watercourses, and pumped from the groundwater reservoir, as well as from various sources on the western slopes of the Rockies.

The principal irrigated farm used for detailed study is located in the southern part of Weld County, east of Platteville, as shown on Figure E-4. It is a 223-hectare [550-acre] field owned by Ray Olin of Platteville and is, in part, in Sections 16 and 17, T.3N., R.66W. The land has gentle, uniform slopes of about two percent draining into the Platte Valley Canal. It is, at its closest boundary, about one km [0.6 mile] from the eastern edge of the town of Platteville. U.S. Highway 85 and the Union Pacific Railroad tracks are located about one km [0.6 mile] to the west of the irrigated farms. Road 32 connects the farm to the town and to the major thoroughfares.

Table E-3. VALUE AND AREA OF CROPS HARVESTED IN WELD, ADAMS AND ARAPAHOE COUNTIES IN 1973

	Weld County			Adams County			Arapahoe County		
Crop	Value, 1,000 dollars	Irrigated (hectares)[a]	Nonirrigated (hectares)[a]	Value, 1,000 dollars	Irrigated (hectares)[a]	Nonirrigated (hectares)[a]	Value, 1,000 dollars	Irrigated (hectares)[a]	Nonirrigated (hectares)[a]
Winter wheat	15,644	1,900	70,100	14,073	1,600	53,000	5,378	200	23,000
Spring wheat	18	40	40	179	400	500	13	...	100
Grain corn	15,284	24,100	200	1,442	2,200	100	125	100	200
Silage corn	35,789	48,000[b]	....	1,560	2,500[b]	....	320	700[b]	....
Barley	3,138	9,500	4,200	921	1,400	5,100	304	40	2,600
Grain sorghum	35	40	200	86	100	300	24	80	100
Dry beans	7,396	7,400	80	122	200	....	...	...	....
Sugar beets	20,033	14,300[b]	....	474	400[b]	....	...	...	....
Oats	388	2,100	500	54	300	300	4	...	80
All hay	14,700	49,200[b]	....	2,644	7,900[b]	....	711	3,200[b]	....
Potatoes	2,285	1,400	....	...	...	....	...	...	....
Other crops	4,529	....	....	2,624	...	....	358	...	....
All crops	119,239	157,980[c]	75,320[c]	24,179	17,000[c]	59,300[c]	7,237	4,320[c]	26,100[c]

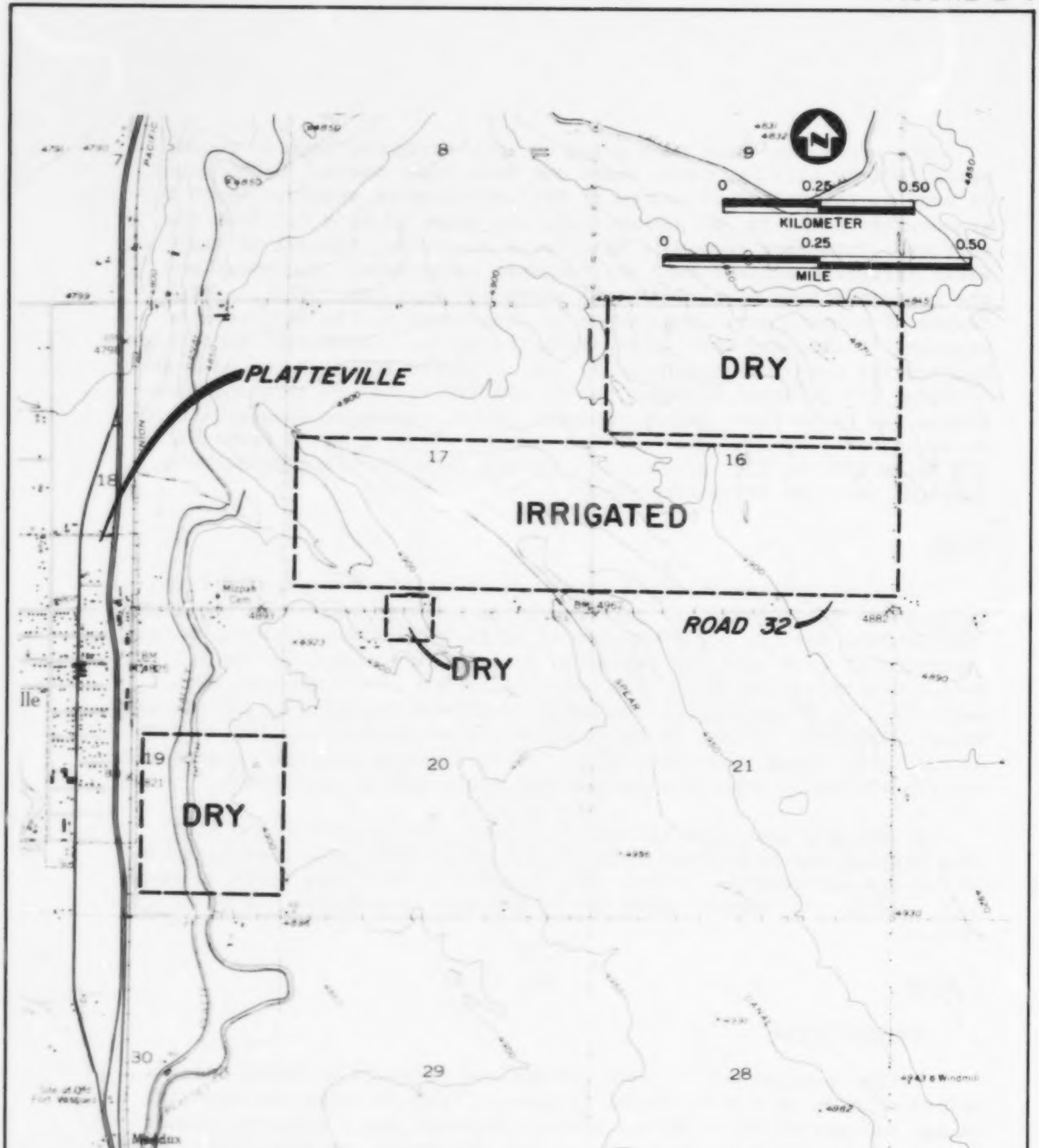
[a] Original source data are in acres: 1 hectare = 2.471 acres.

[b] Total area (irrigated and nonirrigated, if any).

[c] Total areas of harvested crops do not include "other crops" and vary considerably from year to year. Irrigated areas may include minor amounts of nonirrigated areas.

Source: Colorado Department of Agriculture, 1973-1974 Colorado Agricultural Statistics

FIGURE E-4


N
0
0.25
0.50
KILOMETER
0
0.25
0.50
MILE
7
8
9
PLATTEVILLE
DRY
17
16
18
IRRIGATED
ROAD 32
DRY
19
DRY
20
21
30
29
28
STATE HIGHWAY 85
31
32
Mizpah Cem
Maddux
Site of Old Fort Vasquez
Windmill
PACIFIC
UNION
CANAL

REPRESENTATIVE AGRICULTURAL REUSE AREAS

The crops that have been grown on this irrigated farm in recent years include alfalfa, corn, wheat and some sugar beets. Groundwater is used as the principal source of irrigation water supply. Depth to groundwater table is, at places, only one meter [3 to 4 ft] from the surface. Intensive agronomic management practices, typical of high-yield irrigated agriculture, are followed using modern equipment and the recomendations of agricultural extension services. Thus, a high degree of control over application of amendments to the soils can be expected in this and most other irrigated farms. Commercial fertilizer application rates commonly used in the irrigated farms in the area are 87 kg/ha [78 lb/acre] nitrogen (as N) and 100 kg/ha [90 lb/acre] phosphorus (as P) on pinto beans and sugar beets. Barnyard manure is used on sugar beets in the early growing stages. Corn receives from 112 to 225 kg/ha [100 to 200 lb/acre] of nitrogen in anhydrous ammonia form, injected into the irrigation water.

Soils

The most widespread soils which are found in the irrigated farms in southern Weld County and northern Adams County (nearest to the sludge distribution center) are presented in Table E-4. The pertinent characteristics of each soil are tabulated from data furnished by the U.S. Soil Conservation Service. The suitability and limitations of each soil are also presented, on the basis of the characteristics of the soil. These subjective ratings do not include the properties and implications of the crops grown upon these soils. Crop implications are covered under the discussion of impacts upon the food chain and in Appendix D.

It appears that most of the soils under irrigation in the study area possess the properties which would potentially make them suitable for sludge application. There are, however, a few soils (such as Loup-Boel, Valent and Tassel) which may be patently unsuitable for reuse of sludge.

Biology

Vegetation--

Large areas of Weld County and smaller sections of Adams and Arapahoe counties are irrigated farmland. Primary crops are corn for silage and grain, sugar beets, winter wheat and hay. Crops of lesser importance in the study area are barley, dry beans, sorghum, oats, potatoes, fruits and vegetables.

Crops are generally cultivated on a rotational basis that varies with the soil, terrain and available water. Spring-planted crops are seeded in the relatively dry, open-weather months, from early March through June. The ambient temperatures and type of crop determine the

Table E-4. PERTINENT CHARACTERISTICS[a] OF SELECTED SOILS UNDER IRRIGATION IN WELD COUNTY

Soil series, type[b]	Map symbol	Depth to rock, cm[c]	Slope, %	Clay content, %	Cation exchange capacity, meq per 100 g soil	pH[d]	Permeability, cms/hr	Sludge application/reuse		
								Suitability	Limitation	Management needed
Vona, fine sandy loam	51, 51B, 11B	>150	0 to 12	low	very low	6.6 to 7.3 7.4 to 8.4	5 to 15	moderate	low CEC and pH	liming, low rates
Dacono, clay loam	17M	>150	0 to 6	35 to 50	60 to 80	6.6 to 7.8 7.4 to 8.4	0.5 to 1.5	high	low pH	liming
Olney, loamy sand	21B	>150	1 to 10	18 to 35	12 to 20	6.6 to 7.8 7.9 to 8.4	0.5 to 15	moderate	low pH	liming
Altvan, loam	23	>150	0 to 15	17 to 35	--	6.1 to 7.3 7.4 to 9.0	0.05 to 5	moderate	surface texture	--
Thedalund, clay loam	43	50 to 100	0 to 15	18 to 35	--	7.9 to 8.4	1.5 to 5	high	--	--
Loup-Boel, sandy loam	9	(unavailable at the present time)						low	flooding	--
Otero, sandy loam	53, 54	>150	0 to 10	5 to 18	--	7.4 to 8.4	15 to 50	moderate	low CEC, clay content	--
Renohill, clay loam	66B	>150	2 to 15	35 to 50	70 to 100	6.6 to 7.8 7.9 to 9.0	0.05 to 1.5	high	--	--
Valent, fine sand	72	>150	0 to 25	very low	very low	6.6 to 7.8	15 to 50	low	low clay content, low pH	liming

Table E-4 (Continued). PERTINENT CHARACTERISTICS[a] OF SELECTED SOILS UNDER IRRIGATION IN WELD COUNTY

Soil series, type[b]	Map symbol	Depth to rock, cm[c]	Slope, %	Clay content, %	Cation exchange capacity, meq per 100 g soil	pH[d]	Permeability, cms/hr	Sludge application/reuse		
								Suitability	Limitation	Management needed
Tassel, fine sandy loam	84	25 to 50	3 to 25	low	very low	7.4 to 8.4	5 to 50	low	low clay content, depth to bedrock, high permeability	--
Shingle, clay loam	87B	>150	0 to 25	18 to 35	low	7.4 to 9.0	1.5 to 5	moderate	low clay content	--

[a] Basic soil characteristics were obtained from soil survey descriptions and interpretations provided by the USSCS.

[b] Soil type refers to the texture of the surface of the typifying pedon.

[c] 1 cm = 0.3937 in.

[d] The first values refer to soil characteristic in the upper layers (top 15 to 50 cm) and the second values refer to deeper layers.

irrigation water need. Spring and summer rainfall is generally inadequate for most crop production. Harvest of spring grains begins in August and is completed by mid-September. Cutting of dry beans occurs in early September, while corn and sorghum are harvested from late September to mid-October. Sugar beets are harvested from early October to mid-November.

Wildlife--

Wildlife on cultivated lands is generally seasonal and often reflects the type of crop grown in an area. On irrigated farmlands that produce crops such as alfalfa, corn, vegetables and some grains, insectivorous birds predominate. Easily visible spring and summer birds include the western meadowlark, Brewer's blackbird, robin, lark sparrow and grasshopper sparrow. Seed-eating and often crop-eating birds, which are most abundant after planting and at harvest times, include several species of blackbirds, sparrows, migratory waterfowl and, in some areas, the introduced ring-necked pheasant.

Small rodents, generally viewed as agricultural pests, are an important part of the food chain. Burrowing and nest-making animals include pocket gophers, ground squirrels, jackrabbits, harvest mice and meadow voles. Predators which control the small animal populations are the red-tailed hawk, Swainson's hawk, ferruginous hawk and, rarely, the golden-eagle.

The cultivation of former prairie lands has not only changed the overall habitat but has also added a few ecological "niches." Agricultural remnants and surplus areas, such as streambanks, road edges, fencerows, corners and woodland patches are important wildlife shelter and wintering areas. Unharvested strips, stubble and fallow areas provide a valuable food supply during the winter.

Noise

Noise levels of an irrigated farm are similar to those discussed in the section on noise under the heading Sod Farms, above.

Odor

Background odors on irrigated farms are often pleasant and natural: the scents of the freshly turned soil and cut hay and the subtle aromas of growing crops. To some, even the animal manure odors on farms are not particularly unpleasant because of their association with the serenity of rural living. Where chemicals are used (fertilizers, pesticides, herbicides, etc.), temporary odors from their vapors, dusts and other aerosol components spread to surrounding areas, downwind of application areas.

DRYLAND FARMS

In Adams County there are 146,000 ha [360,000 acres] of nonirrigated farms, and in Arapahoe County nearly all farms are nonirrigated (Reference 95). Areas of various crops under nonirrigated culture are shown in Table 22 for Weld, Adams and Arapahoe counties.

An estimated 97,000 ha [240,000 acres] in Adams County is unsuitable for cultivation or is in native grasses used for grazing (Reference 10). These areas are also potential recipients of sludge for improved production of fodder and are treated collectively under the heading Dryland Farms both in the discussion of general environmental characteristics in the present section and in the section on impacts, below.

Wheat and barley are the principal crops grown under dry farming. Generally, dryland farming involves a lower degree of management control than does irrigated farming because of the low relative value of crops produced per unit area of land. Occasional droughts (sometimes lasting for two consecutive years) bring production down to nearly zero. Dryland farming is typically characterized by very extensive land holdings requiring highly mechanized harvesting procedures and equipment. Soil conservation practices, such as rotation fallowing, and water conservation practices, such as scarring the soil surface for better penetration of rainfall and improved water storage, are generally practiced.

In dry-farming areas, sources of water supply are generally at considerable distances from the farms and thus are not threatened by pollution from runoff from those farms. However, in certain other areas (where dry farms are adjacent to irrigated areas or dry river bottoms are used for pasture), the groundwater table may be close to the surface, and intermittent stream courses may be affected by the operations.

Two example sites used for detailed study are (1) east of the sod farm described earlier and (2) near the irrigated farm described above. These sites are shown on Figures E-2 and E-4, respectively.

Topography

Dry farms are generally located on gently sloping, rolling topography with slopes up to about 15 percent. The noncultivated pasture areas, such as dry streambeds, flood plains, hillsides and rocky areas, have less regular topography and have steeper slopes. None of the dry-farmed areas are graded.

Soils

Soils in the dryland farm areas in Adams County are shown in Figure E-4. Some of their characteristics pertinent to sludge application are presented in Table E-5. These soils are deep, almost uniformly noncalcareous in the surface "plow" layer and highly calcareous below (with the exception of Truckton, which is noncalcareous throughout). This pattern leads to low pH in the top layers and alkaline condition in the lower strata. Clay content and cation exchange capacity are generally very low, and the soils are subject to erosion by blowing wind and overland flow of water.

Biology

Vegetation--

Crops are generally cultivated on an annual cycle beginning in the fall. After the first fall rains, winter wheat and winter barley are seeded in September and October. In some cases, erosion and crusting of soils may necessitate a second seeding. Favorable climatic conditions during November and December enable the crops to grow to a strong stand before entering dormancy during January and February. The wheat plants begin greening up by March but are subject to dry, windy conditions during April and May. The amount of spring and summer rain determines the success of the wheat and barley crops. Under favorable conditions, the crops can be harvested during the summer. The higher elevations are often harvested late into the summer. With the fall rains, the dry-farming cycle begins again. Water conservation requires fallowing and scarification of the land surface in the fall.

Wildlife--

Dryland farm areas are generally less intensively cultivated compared to irrigated farm areas. This seasonal monoculture of grain crops leads to somewhat lower diversity of animals than is found in the irrigated farm. Easily visible spring and summer birds include the western meadowlark, Brewer's blackbird, robin, lark sparrow and grasshopper sparrow. Seed-eating and often crop-eating birds, which are most abundant after planting and at harvest times, include several species of blackbird, sparrow, migratory waterfowl and, in some areas, the introduced ring-necked pheasant.

Small rodents, generally viewed as agricultural pests, are an important part of the food chain. Burrowing and nest-making animals include pocket gophers, ground squirrels, jackrabbits, harvest mice and meadow voles. Predators which control the small animal populations are the red-tailed hawk, Swainson's hawk, ferruginous hawk and, rarely, the golden-eagle.

Dryland farming is generally practiced over large areas, with minimal supervision. The unharvested strips, stubble and fallow from these grainfields are an important winter food source for wildlife.

Table E-5. PERTINENT CHARACTERISTICS[a] OF SELECTED SOILS IN DRYLAND FARMING IN ADAMS COUNTY

Soil series, type[b]	Map symbol	Depth to rock, cm[c]	Slope, %	Clay content, %	Cation exchange capacity, meq per 100 g soil	pH[d]	Permeability, cms/hr	Sludge application/reuse		
								Suitability	Limitation	Management needed
Ascalon, sandy loam	As	>150	3 to 5	very low	very low	6.6 to 7.8 7.9 to 9.0	1.6 to 16	moderate	low CEC	runoff control
Platner, loam	Pl	>150	0 to 3	moderate	low	6.6 to 7.3 7.9 to 8.0	0.15 to 5.0	moderate	low CEC	
Stoneham, loam	St	>150	3 to 9	low	low	7.4 to 7.8 7.9 to 8.4	1.6 to 16	low	low CEC	runoff control
Truckton, sandy loam	Tt	>150	1 to 3	very low	very low	6.6 to 7.8	0.13 to 0.3	low	low pH	liming
Vona, loamy sand	Va	>150	3 to 9	very low	very low	6.6 to 8.4	16 to >20	moderate	low CEC	runoff control

[a] Basic soil characteristics were obtained from soil survey descriptions and interpretations provided by the USSCS.

[b] Soil type refers to the texture of the surface of the typifying pedon.

[c] 1 cm = 0.3937 in.

[d] The first values refer to soil characteristic in the upper layers (top 15 to 50 cm) and the second values refer to deeper layers.

Noise

Noise levels of dryland farming are similar to those discussed in the section on noise under the heading Sod Farms, above.

Odor

No particular odors are generally associated with dryland farms. Only during the harvest is the subtle scent of crushed chaff barely noticeable.

LOWRY BOMBING RANGE SLUDGE DISPOSAL AREAS AND LANDFILL

The Lowry Bombing Range is located 24 km [15 miles] east of Denver in Arapahoe County. The Metropolitan Denver Sewage Disposal District No. 1 and the City and County of Denver are currently engaging in three separate, although related, disposal operations on 810 hectares [2,000 acres] of the old bombing range, which is just to the west of the present bombing range. The site is bounded on the west by State Highway 30 and on the south by Airline Road, and falls within Sections 31 and 32, T.4S., R.65W. and Sections 4 and 6, T.5S., R.65W. The locations of the three operations are shown in Figure E-5. Approximately 527 hectares [1,300 acres] are currently being used for the land appliction of dewatered sludge. The City and County of Denver is utilizing 69 hectares [170 acres] in the western part of Section 6 as a solid waste disposal dump. In the eastern part of Section 4, approximately 145 hectares [360 acres] are being used for landfill operations during the winter. These areas will be referred to as Sites A, B and C, respectively.

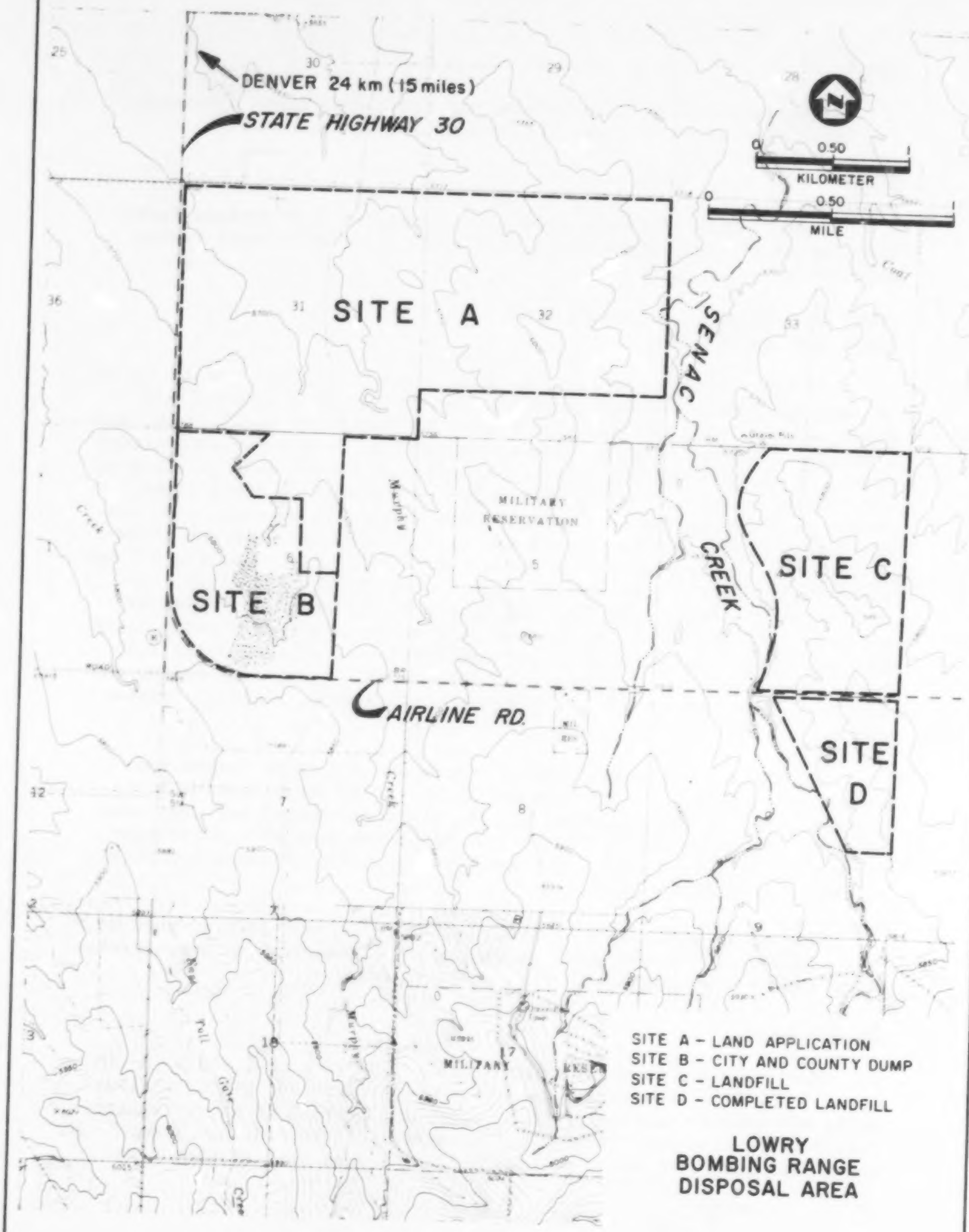
Site C is the winter disposal area where sludge is dumped when the soil is frozen. It is referred to as a deep incorporation area because trenches are excavated and the sludge is dumped and then covered up. Upon completion of the operation, the site will be revegetated with native grasses. The groundwater supply is being monitored to detect groundwater pollution.

Site D, located south of Site C in the northeast part of Section 9, T.4S., R.65W., is a completed winter landfill area that is being revegetated with native grasses.

Topography

The elevation of this area ranges from 1,720 m to 1,785 m [5,650 ft to 5,850 ft]. The relief is subdued, consisting of gently rolling hills and shallow valleys. Murphy Creek and several of its tributaries run from south to north through the western part of Site A. Senac Creek also runs from south to north, lying to the west of Site C and

FIGURE E-5


DENVER 24 km (15 miles)
STATE HIGHWAY 30
0 0.50
KILOMETER
0 0.50
MILE
SITE A
SENAC CREEK
MILITARY RESERVATION
Murphy
Creek
SITE B
SITE C
AIRLINE RD.
SITE D
MILITARY
SITE A - LAND APPLICATION
SITE B - CITY AND COUNTY DUMP
SITE C - LANDFILL
SITE D - COMPLETED LANDFILL

LOWRY
BOMBING RANGE
DISPOSAL AREA

to the east of Site A, and joins Coal Creek to the north of the property. Both creeks are dry most of the year, flowing only during periods of stream runoff. Associated with these watercourses are flat, wide floodplains.

Soils

Soil characteristics for this area are summarized in Table E-6, and occurrence of the soils is shown on Figure E-6. The particular occurrence of lime layering in the soil profile is the most notable property of these soils. A layer of noncalcareous (acidic) surface soil to a depth of from 30 to 60 cm [12 to 23 in.] overlies deeper, highly calcareous (alkaline) materials. This relatively uniform sequence has important implications for sludge application because of the differential solubility of heavy metal compounds at various soil reactions.

Surface layers (to a depth of about 15 to 25 cm [6 to 10 in.] are also coarser (i.e., contain less clay) than are the deeper layers of most soils in the area. This usually gives rise to a corresponding stratification in the cation exchange capacity of the soils. Wind and water erosion hazards are generally severe on the Bombing Range, with great dust clouds generated by trucks and automobiles, even in slow winds.

The Fondis and the Renohill soil series are the most extensive soils in the study area, occurring on approximately 80 percent of the total area, as shown in Figure 13. The Fondis series, which includes the Fondis silt loam and the Fondis-Colby silt loam soil types, occupies approximately 50 percent of Site A. These are deep, well-drained soils with a high water-holding capacity. The surface layer of soil is 15 to 17 cm [6 to 7 in.] thick and rests abruptly on the subsoil, which consists of dense clay 46 to 51 cm [18 to 20 in.] thick. The Fondis soils are high in natural fertility but are moderately susceptible to water and wind erosion. These soils are suited to native grasses and cultivated crops. Smaller units occur on Sites B and C.

The Renohill series, which includes the Renohill-Buick loams and the Renohill-Litle-Thedalund complex, occurs on approximately 30 percent of Sites A and B, and on the majority of Site C. These are moderately deep, well-drained, gently sloping to steep soils that have moderately slow to slow permeability and moderate water-holding capacity. The Renohill soils are moderate in natural fertility, but are susceptible to water and wind erosion. These soils support native grass and are unsuited to cultivation because of the shallowness of the rooting zone and the severe hazard of erosion.

Table E-6. PERTINENT CHARACTERISTICS[a] OF SOILS IN LOWRY BOMBING RANGE SLUDGE DISPOSAL SITES

Soil series, type[b]	Map symbol	Depth to rock, cm[c]	Slope, %	Clay content,[d] %	Cation exchange capacity, meq per 100 g soil	pH[d]	Permeability, cms/hr	Sludge application/disposal		
								Suitability	Limitation	Management needed
Buick, loam	Bx	120 to 180	3 to 9	low	low	6.8 to 8.0 8.0 to 9.0	1.6 to 16	moderate	low CEC	runoff control
Fondis, silt loam	Fd	>150	1 to 5	low high	low moderate high	6.4 to 7.5 7.5 to 9.0	<1.6	high	--	subsoiling
Fondis-Colby, silt loam	Fo	>150	3 to 5	low high	low moderate-high	6.4 to 7.5 7.5 to 9.0	<1.6	high	--	subsoiling
Renohill-Buick, loam	Rh	50 to 100	3 to 9	moderate	moderate	7.5 to 8.5	<1.6	moderate	shallowness	erosion control
Renohill-Litle-Thedalund, complex	Rt	50 to 100	9 to 30	moderate	moderate	7.5 to 8.5	<1.6	moderate	shallowness	erosion control
Nunn, loam	Nl	>150	0 to 3	moderate	moderate	6.5 to 7.0 7.5 to 8.5	<1.6 1.6 to 16	high	--	erosion control
Terry-Olney-Thedalund, sandy loams	Te	60 to 150	5 to 20	very low	very low	6.8 to 7.5	1.6 to 16	moderate	--	erosion control
Weld-Deertrail, silt loam	Wr	>150	0 to 3	low	low	6.5 to 9.0 8.0 to 9.0	<1.6 1.6 to 16	moderate	low CEC	erosion control

Table E-6 (continued). PERTINENT CHARACTERISTICS[a] OF SOILS IN LOWRY BOMBING RANGE SLUDGE DISPOSAL SITES

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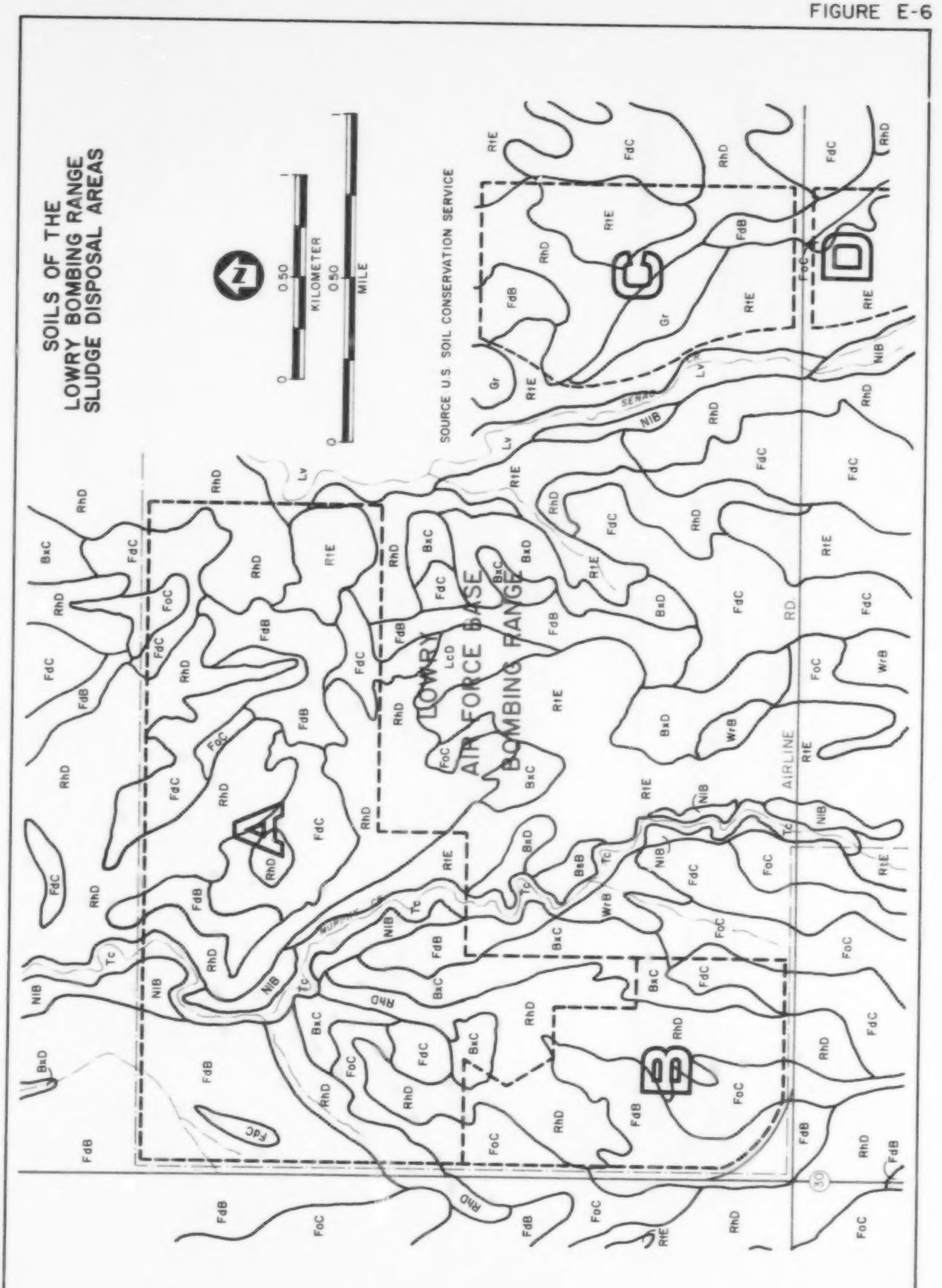
[a] Basic soil characteristics were obtained from soil survey descriptions and interpretations provided by the USSCS.

[b] Soil type refers to the texture of the surface of the typifying pedon.

[c] 1 cm = 0.3937 in.

[d] The first values refer to soil characteristic in the upper layers (top 15 to 30 cm) and the second values refer to deeper layers.

FIGURE E-6



SOILS OF THE LOWRY BOMBING RANGE SLUDGE DISPOSAL AREAS

SOURCE U.S. SOIL CONSERVATION SERVICE

N
0
0.50
1
KILOMETER
0
0.50
1
MILE
LOWRY AIR FORCE BASE BOMBING RANGE
A
B
C
D
AIRLINE RD
30
MURPHY CR
SENAC CR
RhD
RtE
FdC
FdB
FoC
BxC
BxD
BxB
NIB
Tc
Lv
LcD
Gr
WrB

Water

Coal Creek, Senac Creek and Murphy Creek are ephemeral water courses traversing the 850 ha [2,100 acre] disposal area at the Lowry Bombing Range toward the north and northwest. Groundwater occurs both in the alluvial material and in the underlying bedrock, moving in a northwest direction, similarly to the surface waters. Shallow groundwater, lying at a depth of about 18 to 30 m [60 to 90 ft] is of adequate extent and yield to be used for some irrigation and/or domestic purposes. Deeper groundwater levels of the Laramie-Fox Hills aquifer lie at about 520 m [1,700 ft] from the ground surface (Reference 87). This is an important regional aquifer, used principally in the upstream areas in eastern Arapahoe and Adams counties. There are a number of wells downstream, in Denver, tapping this aquifer. In the immediate vicinity of the Lowry Bombing Range disposal area, some 15 domestic wells equipped with electrical or windmill-powered pumps are in active use. About 30 other observation and monitoring wells have been established by the U.S. Geological Survey in cooperation with the Metropolitan Denver Sewage Disposal District No. 1 to study impacts upon groundwater quality. Furthermore, the District maintains surveillance on runoff and surface water quality by sampling and analysis of waters in six catch basins, two springs, two creek stations and two wells.

Biology

Vegetation--

The vegetation of the bombing range can be described as being characteristic of the Uplands Vegetation type. It is primarily pasture and range land that has been subject to grazing for many years. While the original vegetation was probably a short-grass prairie, heavy grazing has changed it to a weedy grass type that contains annual grasses and annual and perennial weeds along with the original perennial bunchgrasses. Good range management practices are needed to prevent overgrazing and to control erosion, particularly on the Renohill soils.

Site A has been subject to the land application of thousands of tons of dewatered sludge since 1969. The sludge is applied in alternating strips of varying widths along 1-m [3-ft] elevation contours, plowed under and planted with wheat and/or grasses, and subsequently used for the grazing of 300 to 500 beef cattle. This site will be used by the City and County of Denver for solid waste disposal as soon as current operations are completed on Site B.

Most of the vegetation that has appeared on Site A can be characterized as weedy species that are fast-growing colonizers of bare soil.

Common sunflower, Russian thistle, summer cypress and tumble pigweed are almost ubiquitous, covering the belts of application with a swathe of greenery that provides little food value to livestock. The practice of livestock grazing on this site has resulted in the almost total de--truction of the planted crops (milo, oats, wheat and sudan) since cattle eat the succulent young shoots as soon as they reach a height of 10 to 20 cm [4 to 8 in.]. Some grasses can be expected to appear over time, although heavy grazing makes it difficult for them to become established.

Wildlife--

Wildlife within the Lowry Bombing Range is characteristic of the Uplands Vegetation unit. The large expanses of rolling plains with low vegetative cover favor small mammal species such as the prairie vole, Ord kangaroo rat, pocket mouse, ground squirrel and jackrabbit. These rodents occupy varying ecological niches and occur sporadically throughout the range area. The openness of the plains area and relatively low animal density contribute to several wide-ranging predator species such as the red-tailed hawk, Swainson's hawk and coyote. The thin stands of cottonwood trees along the seasonal creek drainages in the area are prime roosting areas for the predatory birds and for occasional golden eagles. Several reptiles may be found throughout this arid region, including the bullsnake, prairie rattlesnake and central plains milksnake, which prey primarily upon rodents. Other reptiles, feeding upon insects, are the horned lizard and sagebrush lizard. Infrequent bluffs and cliffs over river bottoms and eroded areas provide a specialized habitat for the bank swallow and kingfisher, which utilize overhangs ind vertical walls for nesting and feeding.

Noise

The countryside is generally noted for its vastness and quietude. The main sources of noise pollution at the Lowry Bombing Range are the roadways traversing the plains, farm equipment, solid waste processing equipment at the landfill, sludge handling and transport vehicles and aircraft. Heavy equipment for solid waste and sludge handling probably generates the greatest daily noise. Military vehicles and aircraft also cause disturbances, although infrequently. However, the relatively low density of the military reservation and its remoteness make all these noise sources insignificant in the overall context.

Odor

There are currently no significant odors originating at any of the sites on the Lowry Bombing Range (Reference 88). There have been no complaints since 1972, when the contractor had piled quantities of sludge without plowing it under. After public hearings in June 1972, the Metropolitan Denver Sewage Disposal District No. 1 revised methods of land application, and current practices do not generate significant odors. Freshly applied sludge can be smelled only at very short distances.

This Appendix contains examples of letters of support for the Metro sludge recycling proposal. The letters were solicited by the Metro District in order to obtain a semi-quantitative estimate of the potential market for the sludge. Many of the writers indicate a desire to have the sludge available for their own uses. This Appendix is not intended to present representative samplings of opinion vis-a-vis the sludge reuse concept. An assessment of the public reactions to this concept is presented in Section VIII.

APPENDIX F

EXAMPLES OF APPROVAL FOR OR INTEREST IN THE PROPOSED PROJECT

CLIMAX MOLYBDENUM COMPANY
A DIVISION OF AMAX INC.
HENDERSON MINE
Box 68
Empire, Colorado 80438
(303) 569-3221

July 25, 1975

Mr. William J. Martin
Director of Resource Recovery and Reuse
Metropolitan Denver Sewage Disposal District No. 1
3100 East 60th Avenue
Commerce City, Colorado 80022

Dear Bill:

This letter is basically to inform you that this year's planting has gone very well. The 300 dry-weight tons of sewage you supplied for mine reclamation revegetation at the Urad mine has been spread on the 15 acres slated for seeding this year, and the grass and trees are beginning to look pretty good. The test plots planted last year are looking very good also, even with 18 consecutive dry days in late June and early July.

Although the whole process is still somewhat in the experimental stage, I can see no reason why things shouldn't go pretty well as planned in the future. The tentative schedule for the future sewage needs is as follows:

Spring 1975	300 tons
Fall 1975	300 tons
Spring 1976	300 tons
Fall 1976	650 tons
Fall 1977	750 tons
Fall 1978	750 tons
Fall 1979	450 tons
Fall 1980	350 tons
TOTAL	3,850 tons

It is the sewage that is making the difference. The sewage is pretty well the key to the whole operation of revegetating the fragmented rock covering the mine tailing. We appreciate everything you are doing to help us in this endeavor.

Sincerely,

Larry F. Brown

Larry F. Brown, Ph.D.
Environmental Control Engineer

LFB:mb

Michael Dulacki
656 Milwaukee St.
Denver, Colorado 80206

Metro Denver Sewage Disposal Dist. #1
3100 E. 60th Avenue
Commerce City, Colorado 80022

Dear Sirs:

I am writing this letter to you to tell you that I endorse the recycling of muncipal wastes in general and that I endorse your particular plan of recycling Denver sewage sludge as a fertilizer and soil conditioner. The possibilities of this plan are many; for one, the Denver Parks Department could use this fertilizer for the city parks. Another example is the use of the fertilizer by private citizens for their own lawns and gardens. I hope you are successful in your efforts to implement this plan.

Sincerely yours,

Michael Dulacki

H. J. BAKER & BRO.
INCORPORATED
IMPORTERS - EXPORTERS
ORGANIC AND CHEMICAL FERTILIZER MATERIALS
ANIMAL FEEDING SUPPLEMENTS
OILS, FATS AND MEALS
360 LEXINGTON AVENUE
NEW YORK, NEW YORK 10017

TLANTA
ORT SMITH
ORT WORTH
ITTLE ROCK
EW ORLEANS
HILADELPHIA
AVANNAH
AMPA

AMBURG, WEST GERMANY
AN JOSE, COSTA RICA

TELEPHONE
212-867-0200
CABLE ADDRESS
"BAKERBRO"
TELEX 1-2487
420944
223482

July 29, 1975

Metropolitan Denver Sewage Disposal
District No. 1
Commerce City, Colorado

Gentlemen:

We noticed in the July 28th issue of the publication Air/Water Pollution Report, that you have been granted $76,029 to study the effect of feeding to cattle, crops grown on sludge amended soils. From our letterhead, you will see that we are in the fertilizer and feeding materials business, and for many, many, years, we have actively sold heat dried activated sewage sludge to the fertilizer industry. Some of this sludge finds its way on to pasture lands as part of a complete mixed fertilizer. Consequently, we will be keenly interested in knowing the outcome of your study, if this information could be made available to us. As a matter of fact, we would like to know whether you are recovering and heat drying your sludge and whether you would be in a position to offer us tonnage. We are currently selling, nationally, the entire output of the Metropolitan Sanitary District of Chicago for the people who have the contract with them and can handle additional supply.

We look forward to the pleasure of hearing from you.

Very truly yours,

H. J. BAKER & BRO., INC.

J. W. Reisack
Vice President

JWR/nw

BAKERBRO CENTROAMERICANA S.A., COSTA RICA • NUTRITION PRODUCTS DIVISIONS, NEW ORLEANS, PHILADELPHIA • THE KAINIT DIVISION, SAVANNAH • POULTRY BY-PRODUCTS, INC., HANCEVILLE, ALABAMA • THE PRO-PAK CORPORATION, FERNANDINA BEACH, FLORIDA • H. J. BAKER & BRO. (CANADA) LTD., MONTREAL

The CITY of NORTHGLENN
10969 IRMA DRIVE
NORTHGLENN, COLORADO 80233
(303) 452-1941

Bill Martin
C/O Metro Denver Sewer
3100 E. 60th Avenue
Commerce City, CO 80022

We are extremely interested in obtaining anarobically digested stabilized sludge for use on our parks and greenways. We understand that this material will be made available in the near future and would like to be contacted so we can use this valuable resource. We can use approximately 200 to 500 tons annually.

Could you please send me the Chemical analysis of the material also, what method will be used in transporting to Northglenn.

Thank you,

Jack DeBell

Jack DeBell
Superintendent of Public Works
City of Northglenn

JDB/cw

office of the director of community works

City of Commerce City

4407 East 60th Avenue
Commerce City, Colorado 80022
TELEPHONE (303) 287-3485

COMMUNITY
DEVELOPMENT

August 11, 1975

Mr. William J. Martin, Director
Resource Recovery & Reuse
Metropolitan Denver Sewage Disposal District #1
3100 East 60th Avenue
Commerce City, CO 80022

Dear Mr. Martin:

I am writing this letter pursuant to our conversation of Thursday, August 7, 1975.

The City of Commerce City has been strongly considering and hopes at some future date using "sludge" as a fertilizer for both new park development and park maintenance. The City has approximately 40-acres of developed park and open space which we are fertilizing (commercial) a minimum of three times a year. As well, we are planning to construct between 10 and 15 additional acres each year for the next four years in which we have been applying manure for topsoil development.

We would like to substitute your sludge in both these instances.

Sincerely,

Dale W Gilbert

Dale W. Gilbert
Director of Community Development

th

August, 1974

TO: THE METROPOLITAN DENVER SEWAGE DISPOSAL DISTRICT NO. 1

We, the undersigned, in the interests of minimizing environmental pollution and conserving our resources, wish to affirm our support for the recycling of municipal wastes. In particular, we strongly support efforts which would make municiple wastes available to the public for use as an organic fertilizer.

NAME	ADDRESS	ZIP

This petition was signed by 461 persons, primarily in the Metropolitan Denver area.

COGMA

COLORADO ORGANIC GROWERS' AND MARKETERS' ASSOCIATION

2555 W. 37th AVE.
DENVER, COLORADO 80211
477-6291

othe Metropolitan Denver Sewage Disposal District #1.

We the undersigned individuals, residents of Metropolitan Denver comitted to the usage of natural fertilizers only and convinced that, as axpayers, we are entitled to stabilized,dry or semi-dried activated sludge nd concentrated anaerobic-produced sludge, semi-dry or dried.

Name	Address	land area	1/4 ton	1/2 ton	1 ton	(+

This petition was signed by 15 persons who requested a total of 37 1/2 tons of sludge.

This Appendix comprises a reproduction of the tabulation of the environmental evaluation matrix used by the facilities planner (CH2M-Hill) in selecting site B-2 from the three finalists for a sludge drying and distribution site. Even though site B-2 has been selected by the planners as the most favorable location, nagging problems remain with respect to neighborhood acceptance and potential market proximity. For more information on the environmental, engineering and cost factors weighed in the process of site selection refer to Reference 8 in Section IX of the main body of the EIS.

	CONSIDERATION	CRITERIA	SITE A	SITE A 2	SITE B 2
SITE	Overall land requirements	Are 2000 acres available?	Yes	Yes	Yes
	Future expansion	Can this site be expanded?	Expansion of this site to the west would be encumbered by a potential subdivision development. Expansion to the east would crowd already existing subdivisions. Expansion to the north and south is possible, however relocation of a major east-west arterial would be required to the north.	Expansion of this site could occur in all directions except to the northeast due to an existing subdivision.	Expansion of this site could occur in all directions except the southeast and south due to a natural drainage course that exists in the area. However, Irondale Road would need to be relocated to expand to the south.
	On site buffer	Are 1320 feet of buffer available? (Buffer area is meant to include injection and demonstration plots.)	Narrow site configuration would require the east and west buffers to be less than the 1320 feet.	Yes	Yes
	Ease of Acquisition	How many property owners are involved?	There are three property owners, including the state.	There are four property owners.	There are six property owners, including the state.
ACCESS	Distance from treatment plant	How many miles?	The center of the site is approximately 23 road miles from the treatment plant.	The center of the site is approximately 21 road miles from the treatment plant.	The center of the site is approximately 25 road miles from the treatment plant.
	Arterial	Where are the nearest major arterials suitable for moderate to heavy truck traffic?	Bromley Lane borders the north boundary of the site. It functions as a major east-west arterial in the region with posted speeds of 55 MPH.	Hacks Mount Road is the major north-south route marking the eastern boundary of the site with speeds of 55 MPH.	Irondale Road is the southern boundary to the site. It is a major east-west arterial in the region with a speed limit of 55 MPH.
	Railroad	Where is the nearest railroad line?	Railroad lines lie 4 miles to the west of the site.	A railroad line is located 4 miles to the west of the site.	The nearest railroad line lies 16 miles to the west of the site.
	Near potential users	Is this site adjacent to possible customers?	The A-1 site is approximately 11 miles from the center of a potential market area surrounding Brighton. The site also lies approximately 18 miles from the center of a second identifiable market area to the east.	The A-2 site is approximately 12 miles from the center of a potential market area surrounding Brighton. The site also lies approximately 18 miles from the center of a second identifiable market area to the east.	Site B-2 is approximately 23 miles from the center of a potential market area surrounding Brighton. This site also lies approximately [illegible] miles west of the center of a second identifiable market area to the east.
	Utilities	Are power, water and sewers available?	Power is the only public utility that is available to the site.	Same as Site A.	Same as Site A.
LAND USE	Zoning	What is current zoning? Can zoning be changed?	Currently, this site is classified in an agricultural A-2 zone, which allows a broad scope of agricultural endeavors. The designation attempts to control the intrusion of intensive residential, industrial, commercial or other nonagricultural uses. Zoning in Adams County can be altered by the approval of the Planning Commission and the Board of County Commissioners. The criteria for zone changes will be closely aligned with the policies and intent of the comprehensive plan.	Same as Site A.	Same as Site A.
	In conformance with existing plans	Would this site conform to county, region and state plans, both existing and proposed?	Local planning for Adams County is in the process of being updated. Earlier indications suggest that the emphasis will remain on agricultural usage. However, continued pressures for large lot subdivision suggest the county may relax its policies in future land use planning concerning the intrusion of a suitable mix of suburban development and agriculture. The proposed site usage represents a special use not normally considered in comprehensive land use planning. Conformity to present land usage will depend on how well the operation can co-exist with adjacent land usage. Adams County planners have acknowledged that conformity with surrounding land use would be enforced through items such as a comprehensive plan revision, rezoning and special use permits.	Same as Site A.	Local planning for Adams County is in the process of being updated. Earlier indications from the planning effort do not suggest substantial changes from current usage. The emphasis in the area will remain on agricultural. The proposed site usage represents a special use not normally considered in comprehensive land use planning. Conformity will be a question of how well the operation can co-exist with adjacent properties. Adams County planners have acknowledged that conformity with surrounding land use would be enforced through items such as a comprehensive plan revision, rezoning and special use permits.
	Compatible with surrounding users	Is this site located away from recreational, residential, natural area, etc.?	A residential subdivision lies 1 mile east of the southeast corner of the property. There are approximately 30 homes occupying 5- and 10-acre parcels. A large lot (2 [illegible] 5) subdivision is proposed to be developed adjacent to the western border of the site. At this writing, no approvals by the county have been made for this development.	A residential subdivision is located [illegible] mile from the northeast corner of the site. There are approximately 30 homes occupying 5- to 10-acre lots.	With the exception of one house, a barn, and storage sheds located near the northern edge of the proposed site, and one house 1/4 mile from the eastern edge, the surrounding area is in extensive agricultural use.
		Would the process facility require the disruption or relocation of existing public facilities?	Though an electrical transmission line occupies the western edge of the property, no disruption or relocation of the line would be required. Natural gas mains run north-south along the western edge of the property, and east-west oriented mains bisect the property in two locations. Relocation of these east-west mains is considered improbable. Therefore, site design would have to minimize any accidental disturbances of these gas mains or any encumbrance to their access.	An Electrical transmission line borders the western edge of the site. No disruption or relocation of this line would be required. A natural gas main cuts across the southeast corner of the site. Relocation of this main is considered improbable; therefore, site design would have to minimize any accidental disturbances of this gas main or any encumbrance to its access. Three gas wells are also located on the site.	One natural gas pump is scheduled to be built within the next year.
	Current land use	What is the current land use?	The property is currently in extensive agricultural use, with less than 100 acres in pasture land. Wheat crops are rotated yearly on the site always leaving approximately 50% of the site fallow. An electrical transmission line occupies a corridor running the full length of the western edge of the property.	The property is currently in extensive agricultural use, with approximately 50% of the land in wheat crops and 50% fallow. These crops are rotated yearly. An electrical transmission line occupies a corridor running the full length of the western edge of the property.	Current land use is in extensive agricultural production. Wheat crops are rotated on the site, leaving approximately 50% of the acreage fallow per year. A 150-acre natural drainage area is located in the southeast corner of the site.
	Land use alternatives	What are the alternative uses being considered for this site?	An alternative would be partial agricultural use with some large suburban development with 5- to 10-acre lots.	The site could be preserved in agricultural use. It could eventually be subdivided into large 5- and 10-acre residential lots.	An alternative to the present use of the land could be to preserve it in its existing state or to eventually subdivide the area into large suburban lots of 5 to 10 acres.
		What would be effect of beneficial reuse?	It has been recognized by soil micro-biologist that the soil is an ideal ecosystem to absorb and integrate our wastes. Predicting the degree of compatibility of sludge and soil, however, is complicated by not knowing the ability of the soil to deal with recalcitrants, toxic chemicals, heavy metals, and infectious microorganisms. There is strong evidence that improved tilth will occur, resulting in greater water holding capacity. However, generalized statements, regarding the maintenance and enhancement of soil fertility and agricultural productivity are premature. Continued demonstration and research of sludge and soil compatibility during the project can be cited as the most substantial safeguard of irreversible soil effects either at the site or the marketing region.	Same as Site A.	Same as Site A.
SOIL AND GEOLOGY	Soil Characteristics	Soil Series	Truckton Loamy sand, eroded Truckton Loamy sand Ascalon Loamy sand Blakeland Loamy sand	Ascalon Loamy Sand Ascalon Sandy loam ULM Loam Truckton Loamy sand Blakeland Loamy sand Nunn loam	Platner Loam Ascalon Sandy loam Renohill Loam

	CONSIDERATION	CRITERIA	SITE A	SITE A 2	SITE B 2
SOIL AND GEOLOGY (Continued)		Permeability	Mostly rapid to moderately rapid.	Mostly moderate to rapid.	Mostly moderately slow.
		What are the effects to the physical, structural, chemical and biological properties of soil from the potential of pollutant accumulation? Would the project on this site alter soil erosion condition?	The amount of area exposed to soil erosion will be lessened by the placement of extensive drying basins. Localized soil erosion on site may be increased by sludge injection activity and the presence of structural features. Sludge injection activity would be periodically conducted with repeated application during summer months. Repeated soil disturbances would increase erosion susceptibility of already highly erosive native soils. The earthen berms surrounding the drying basins would be exposed to stronger wind forces causing increased soil erosion potential.	Same as Site A.	Like alternatives A-1 and A-2, soil erosion at this site will be lessened by the placement of the drying basins. However, unlike the other sites, localized soil erosion problems caused by injection activity and structural features would not be as severe. The site B-2 soils are characterized as loams with underlying clays. Their resistance to wind erosion is considered to be greater.
	Mineral Resource	Are there any mineral resources on or beneath the site?	The vicinity is underlain by lignite coal. The specific coal deposits underlying this site are not known. There is one gas well on the site and the project is not believed to provide any encumbrances for further development of this resource. Oil is another resource drawn from the vicinity. No oil wells are currently on this site.	The vicinity is underlain by lignite coal. The specific deposits underlying this site are not known. There are two gas wells on the site, however, the project is not believed to provide any encumbrances for further development of this resource. Oil is another resource drawn from the vicinity. No oil wells are currently on this site.	The vicinity is underlain by lignite coal. The specific deposits underlying this site are not known. The project is not believed to provide an encumbrance for development of resources. Oil is another resource drawn from the vicinity. No oil wells are currently on this site.
	Subsurface	Do geological substrata at this site permit the interchange of surface waters with water supply aquifers? Will natural substrata drain readily and not be subject to the effects of slumping or saturation?	The site is underlain by coarse-grained material that would not subject the surface to slumping or the subsurface conditions to saturation.	Same as Site A.	Preliminary site investigation in a limited area indicates underlying clays. This material is more susceptible to saturation than is the material native to the other sites. Saturation of this material ultimately impedes infiltration from drying basins and subsurface injection and thus could result in the need for greater drying times in the basins.
	Terrain	Does the site have a number of suitable locations for process facilities and storage area without major earth work?	Site contours are considered ideal for facility placement without major earth work.	Site contours are considered good for facility placement without major earth work.	The rolling topography of Site B-2 would require more earth work for facility placement than would alternative sites.
		Will slides or slippage present a problem at this site?	Slopes on the site are slight. No slides would be anticipated from the operation at this site.		Slopes on the site are slight to moderate, however, no slides would be anticipated from the operation at this site.
		Is offsite fill or borrow required to construct the process facilities at this site?	Not known at this time.	Not known at this time.	Not known at this time.
		Are there unique or scientifically significant geologic configurations that would be adversely affected?	None are known to exist.	None are known to exist.	None are known to exist.
CLIMATIC CONDITIONS	Wind Patterns	Would wind patterns at this site be likely to extend the effect of odor, dust and noise to development surrounding the property?	Prevailing wind directions are generally from the south by southwest. Extended effects of odors and dust, caused by winds would not affect any surrounding developed properties, with the possible exception of two permanent dwellings on the western border. A residential development proposed on the western border could be affected by existing wind patterns and become the source of repeated complaints.	Prevailing wind directions are generally from the south by southwest. Extended effects of odor and dust, caused by wind could affect a residential subdivision near the northeast corner of the property. Because of its relative position to the site, this subdivision could become the source of repeated complaints.	Prevailing wind directions are generally from the south by southwest. Extended effects of odor and dust, would not affect any surrounding development.
		Is this site subject to wind erosion or deposition?	The site is affected by high winds and has native soil which is prone to wind erosion.	Same as Site A.	The site is affected by high winds, however, native soil is more resistant to soil erosion than are the soils of the alternative sites.
WATER	Storm runoff	Is this site located away from flood plain areas, with no flooding problems?	There are no major drainage ways or flood areas on the site.	Same as Site A.	A drainage way does exist on the southeast corner of the property. Site design would exclude any activity in this corner of the property.
		Would the process operation at this site adversely alter the movement of runoff?	Storm runoff movement away from the site would be collected by a perimeter drainage system and stored. Depending upon its quality, storm runoff would either be released slowly into a natural offsite drainage way or sprinkled over the buffer areas.	Same as Site A.	Subsurface injection in heavier, easily saturated soils may cause greater runoff to occur during certain periods.
	Surface/Ground	Will ground or surface water be affected by this project?	It is not anticipated that ground or surface water would be affected. The design for this project includes extensive surface water catchment facilities and numerous ground water monitoring wells. Should surface or subsurface water be affected, it would be possible to implement strategies for the treatment of effected water.	Same as Site A.	Same as Site A.
		Does the site currently have serious drainage problems?	None have been observed or known to exist.	Same as Site A.	Same as Site A.
ECOLOGY	Vegetation	What vegetative cover exists on the alternate sites?	Site A has a stand of trees located approximately midway along the western boundary. This is the only substantial stand in the area.	The site has a 6-acre island of over-grazed prairie located in the center.	The site has a 4-acre stand of over-grazed prairie located within the southeast corner of the [illegible] zone.
		Is this vegetative cover essential to the ecology of the region?	The stand of trees is essential to wildlife habitat, especially owls and hawks.	The 6-acre island of over-grazed prairie is not considered essential to the ecology of the region.	The 4-acre island of over-grazed prairie is not considered essential to the ecology of the region.
		Are unique or rare species present?	No rare or unique species of vegetation are present on the site.	Same as Site A.	Same as Site A.
		Are shrubs and trees available to screen area and absorb noise?	Except for the stand of trees on the western boundary of the site, shrubs and trees are not available on the site to screen the area and absorb noise.	Shrubs and trees are not available on the site to screen the area and absorb noise.	Same as Site A-2.
	Animals	Would the project at this site destroy essential habitats for wildlife?	Essential wildlife habitats would be destroyed if the stand of trees on the site was destroyed because owls and hawks inhabit the stand. There is enough surrounding area for other species of animals.	A coyote den was located on the site. Coyotes are territorial animals. When they are forced to move, there is the chance that they would be unable to relocate. However, the coyote is on the increase; thus, to alter the use of the area is not considered to damage essential habitats for wildlife. For non-territorial animals, there is enough area for the animals to relocate.	Essential wildlife habitats were not found on the site. There is enough area for the animals to relocate.
		What species are present on the alternate sites?	Species identified in the general vicinity of the site are rabbits, mice, owls, hawks and coyotes. Except for the coyotes, which are territorial animals, the species do well in disturbed areas.	Same as Site A.	Same as Site A.
		Are any of these species considered to be rare or endangered?	None of these species are rare or endangered.	Same as Site A.	Same as Site A.
		Would location of the project at this site adversely affect fish life?	No fish life was located on the site.	Same as Site A.	Same as Site A.
		Will domestic animals be affected by location of the project at this site?	Domestic animals would not be affected by location of a project at this site.	Same as Site A.	Same as Site A.

	CONSIDERATION	CRITERIA	SITE A	SITE A-2	SITE B-2
MISCELLANEOUS	Visual	At which site would the project be least visible to surrounding areas?	It is generally agreed that the visual image of the project would deviate from the visual character of its surroundings. However, the topographical position of site A provides the least offensive visual impression of any of the sites. Neither stationary or transient viewers would have a prominent view of the project site from residential dwellings or arterial routes. Buffered areas surrounding the site would help maintain visual compatibility with surrounding area.	Site A-2 is at a visual disadvantage because it lies in a topographic bowl. The project could be viewed from most areas surrounding the site. The most obvious view of the project would be provided along the eastern edge. A residential subdivision near the northeast corner would have a view of the site at a distance of approximately 1/2 to 3/4 of a mile. Transient viewers could easily view the site from Hacksmount Road.	Site B-2 is located in an area where there are no surrounding residences for a distance of one or more miles. With the exception of one resident located near the northern edge, transient viewers on Irondale Road could view the project.
		How easily can the site be landscaped and screened?	Topographical position provides a natural screen from most viewing areas.	No natural screen exists.	No natural screen exists.
	Noise	Would the project create increased noise in surrounding areas?	Intermittent noise levels would increase on and around the immediate vicinity of the site during daylight hours due to equipment operation and truck travel to and from the site. Stationary pumps will be placed underground or in enclosed structures eliminating any noise.	Same as Site A.	Same as Site A.
	Traffic	Will the project create increased traffic loads?	Traffic loads in Bromley Lane will increase, particularly during the spring and fall (6 months), when sludge is acquired by farmers.	Traffic loads on Hacksmount Road will increase particularly during the spring and fall (6 months) when sludge is acquired by farmers.	Traffic loads on Irondale Road will increase during the spring and fall (6 months) when sludge is acquired by farmers.
	Historic Value	Is this site located on or adjacent to area of historic interest?	An archeological investigation of this site found that it is located near an area of historic interest.	An archeological investigation identified an area of historic interest off the northwest corner of the site. The following items were found: fragments of metates, 6 fragments of at least 2 different grinding slabs, all fine grain reddish sandstone; 3 fragments for 3 different manos, 2 fine-grain reddish sandstone and 1 granite; 2 chipped stones, 1 brown and dark brown alternate layered petrified wood, one reddish quartzite. As a result of plowing and wind action, the cultural deposit is broadly scattered in a random manner.	An archeological investigation found that this site is not located on or near an area of historic interest.
	Community reaction	How would the community react to locating the project at this site?	Opposition has been expressed to locating the project in Adams County. This opposition has been voiced by the local residents and the County Board of Commissioners.	Same as Site A.	Same as Site-A.
COST	Capital	Dollars	The capital costs total $16,016,000, based on 1974 costs.	The capital costs total $15,673,000, based on 1974 costs.	The capital costs total $17,639,000, based on 1974 costs.
	Annual operation and maintenance	Dollars/year	The 1985 operation and maintenance costs will be approximately $678,000.	The 1985 operation and maintenance costs will be approximately $675,000.	The 1985 operation and maintenance costs will be approximately $688,000.
	Present worth	Dollars	$11,948,000 based on 1974 costs.	$11,695,000 based on 1974 costs.	$12,899,000 based on 1974 costs.
RELIABILITY	Pumping	How many pumps are required?	There are 4 pump systems, plus 2 standby pump systems. A pump system is composed of 2 individual pumps and one motor.	Same as Site A.	Same as Site A.
	Pipeline	What is the distance to site?	The pipeline distance from the metro plant to Site A is approximately 23 miles.	The pipeline distance from the metro plant to Site A-2 is approximately 19 miles.	The pipeline distance from the metro plant to site B-2 is approximately 25 miles.